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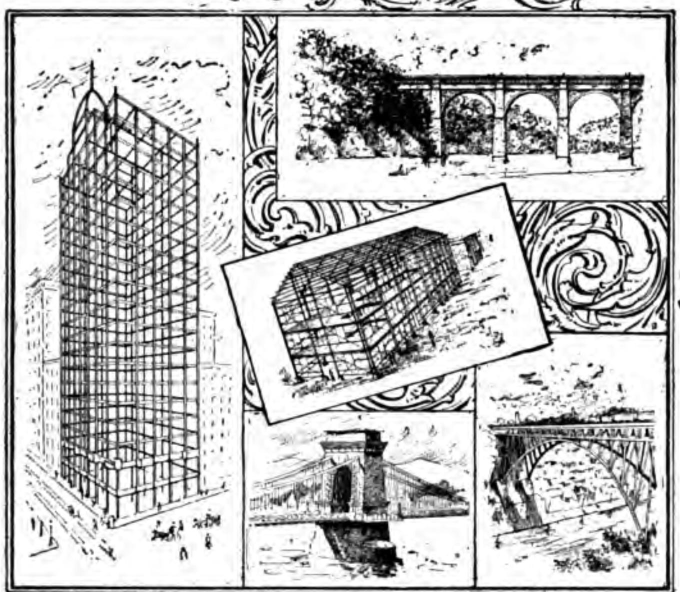
BRIDGES

AND FRAMED STRUCTURES

AN ILLUSTRATED MONTHLY MAGAZINE



FOR
ENGINEERS
ARCHITECTS
INSPECTORS
SUPERINTENDENTS
MANUFACTURERS

VIADUCTS
BUILDINGS
MASONRY

LEADING FEATURES OF THIS NUMBER

THE D·H·RANCK· PUB· CO· CHICAGO·

Contents for April, 1899.

*Illustrated.

THE PUBLISHERS' PLANS.

We take pleasure in announcing that the succeeding issues of "BRIDGES AND FRAMED STRUCTURES" will contain articles of more than passing interest to all our readers. Our aim will be to have each and every article of such value that every one will save and bind the magazines, so that they can be kept at hand for reference on the subjects treated of—which will in a short time be of such variety as to make the volumes practically an encyclopædia.

Mr. Frank C. Osborn, M. Am. Soc. of Civil Engineers, will have an article in the May number on **the Inspection of Iron and Steel.** This will give in detail the methods which are pursued in the work of mill and shop inspection, the various blanks used for records and reports being shown in reduced size. He will continue the subject in the June number, the title being **What Inspection Accomplishes.**

Recent English Practice in Bridges and Framed Structures is the title of an article by Mr. A. D. Ottewell, Consulting Engineer of Derby, England. After an experience with one of the largest bridge building firms in England, he was engaged for years on bridge work in the United States, and is especially well qualified to write on this subject in a manner entertaining to American readers.

The subject of **Architecture of Bridges** which is discussed in this number will be continued in the May number, the sub-title being **Parapets and Balustrades.** The subject will be continued in succeeding issues as space will permit. There will be numerous illustrations.

Bridge Evolution as Relating to Southern California, by Mr. C. E. Fowler, M. Am. Soc. C. E., will appear in the May and June issues. The first installment is an interesting review of the history of bridge engineering, illustrations being presented to elucidate the text. The second installment will embody the results of Mr. Fowler's observations during a visit there, upon the needs of Southern California in bridge construction and the most desirable types to build. This will be elegantly illustrated.

Mr. John Cassan Wait, Consulting Engineering Attorney, author of "Engineering and Architectural Jurisprudence," will contribute articles on **Law Points on the Co-relation of the Bridge Contract and Specifications,** to the May and June numbers. Mr. Wait will also conduct a *Department of Law* for the magazine, an installment to appear each issue.

Concrete in Railway Bridge Construction will be the subject of a most timely and interesting article by Mr. H. W. Parkhurst, M. Am. Soc. C. E., Engineer of Bridges for the Illinois Central Railroad. This road is taking the lead in construction of this kind, and the methods used, as well as the results obtained, will be of especial value. The illustrations will be numerous and handsome half-tone plates.

The remarkable study on the **Chemical and Physical Constitution of Steel,** by Mr. Wm. R. Webster, Consulting Metallurgical Engineer, will be followed by other articles on steel manufacture by the best authorities.

The progress of shop methods will be shown to some extent in a review in the May number on **Notable New Bridge Shop Machines.** This will be followed by special articles on subjects of methods of work and management.

The new Rhine Bridge at Dusseldorf will be the subject of an article describing this elegant new bridge.

The Recent Bridge Work of India will be the title of a review for June, while the subject of Russian Bridges will be discussed for July. During the year the bridge work of other countries will be discussed.

The series of biographical sketches will be continued in May by a biography of Albert Fink, with illustrations and portraits of him as a young man, a middle-aged man, and one taken shortly before his death.

C. Shaler Smith's biography will appear in the June number with portraits taken at various ages and numerous large half tone views of his bridges.

Other announcements will be made, from time to time, of notable contributions and of matters of interest to our readers.

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VOL. I. Bridges and Framed Structures. NO. 1.

AUTHORS AND THEIR ARTICLES IN THIS NUMBER.

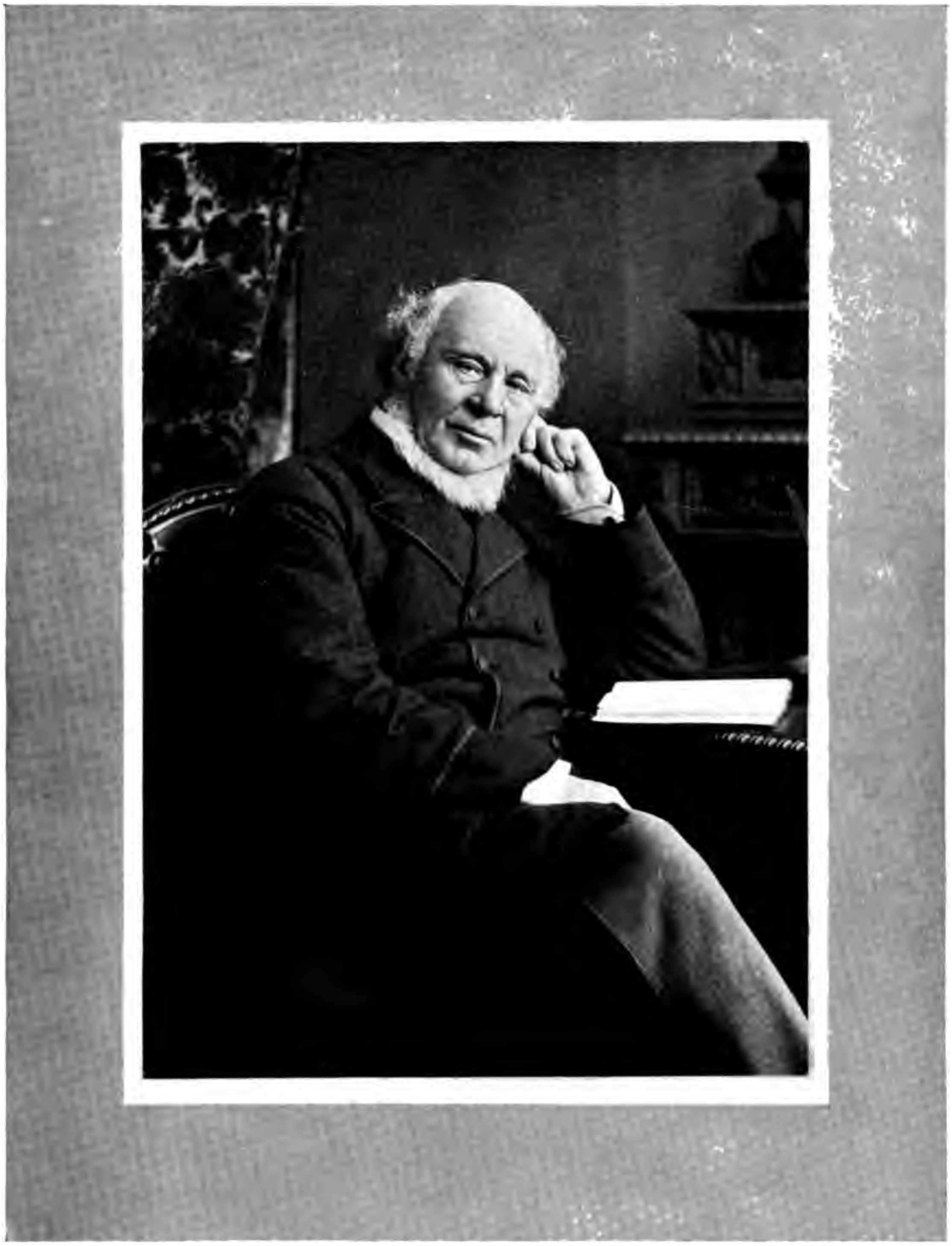
MALVERD A. HOWE—b. Northfield, Vt., 1863, and received early education in the graded schools of that place. Graduated from Norwich University 1882, Degree B. S. Graduated from Thayer School of Civil Engineering, Hanover, N. H., 1886, Degree C. E. Between 1882 and 1886 engaged for two years in miscellaneous railway work. After graduating from Thayer School entered drafting department of the Edge Moor Bridge Co., leaving to take the position of Instructor of Surveying and Drawing in the Lawrence Scientific School, Harvard University, remaining one year. In 1887 accepted present position as Professor Civil Engineering in Rose Polytechnic Institute, Terre Haute, Ind.

Member Am. Soc. C. E. and Engineers' Club of St. Louis; also Society for the Promotion of Engineering Education. Author of "Retaining Walls for Earth"; "Theory of Continuous Girder"; "Sabula Draw by Graphics"; "A Treatise on Arches," and miscellaneous papers.

A. W. JONES—b. Yellow Springs, O. B. A. from Antioch College, 1884; post graduate course at Ohio State University in Civil Engineering. Appointed Chief Engineer's Clerk on Scioto Valley Ry. May, 1886, and Asst. Engineer same road, August, 1886; on sale of road to Norfolk & Western, February, 1890, became Asst. Engineer on Ohio extension of that road; resigned June, 1890, to accept Asst. Engineership on Wisconsin Central Lines; after absorption of this road by Northern Pacific remained in same position with headquarters at Chicago; season of 1894 locating lines in Northern Minnesota for Minnesota Canal Co.; and at present time in general Civil Engineering practice at Chillicothe, O., and Engineer for Ross county.

EDSON MASON SCOFIELD—b. in 1867, at Hermon, N. Y. After completing his common school education, he entered Union College at Schenectady N. Y., graduating with the Degree of C. E. in 1888. Was instructor in Mathematics at Rockland College, Nyack, N. Y., for one year. Was principal assistant with Mr. Edwin Thacher, M. Am. Soc. C. E., at Louisville, Ky., for five years, during which time he was engaged in many notable pieces of railroad and highway bridge work; also made several important improvements on the calculating slide rule, and is author of one of the standard publications on its use. For the past five years he has been principal Asst. Engineer for the Youngstown Bridge Co., of Youngstown, Ohio, in charge of estimating department. Many of the plans which have been worked up were for notable arch and cantilever bridges which were constructed.

WILLIAM R. WEBSTER—A graduate in 1875 of the Massachusetts Institute of Technology in mining engineering and metallurgy. Was employed with some of the large steel manufacturing concerns for a number of years, and also in bridge construction. For his investigation of the "Chemical Constitution and Physical Properties of Steel," one of the most extensive and painstaking pieces of work ever done in this branch of science, he received the John Scott Legacy Premium and Medal from the Franklin Institute of Philadelphia. He is at present located at Philadelphia as Consulting and Inspecting Engineer on iron and steel.

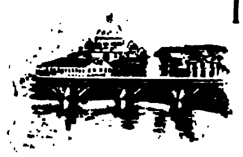


SIR JOHN FOWLER

BRIDGES AND FRAMED STRUCTURES.

VOLUME I. APRIL, 1899. NUMBER 1.

SIR JOHN FOWLER



THE period over which Sir John Fowler's career extended practically coincides with that of the profession of modern engineering. In saying this we do not forget the illustrious men who preceded him, such as Telford, Trevithick, Watt, Smeaton, and Rennie. But these all flourished before the manufacture of iron, and the tools for working it had so far progressed that it was readily available for every-day use. Many of them executed splendid works in brick and stone, works which will uphold their reputations for centuries, and others of them were capital mechanics. But it was not then practicable to use iron, and particularly wrought iron, for large structural purposes. It is worth while to recall a few instances in exemplification of this fact which is often forgotten. The first flour mill which had iron wheels and shafting was erected by Rennie in 1788. The first iron bridge was designed by French-Italian engineers in 1755, and was attempted to be constructed at Lyons, but the founders proved unable to cast it. In 1777 a cast iron bridge of 100-foot span was erected at Coalbrookdale, and this was followed in 1796 by one over the Wear. This latter had been constructed to the directions of the celebrated Tom Paine for a different site. A third bridge was erected by Telford over the Severn about the same date, and he constructed four other cast iron bridges before the century terminated. Rennie's first iron bridge was opened in 1803 at Boston. It is thus shown that the employment of iron on a large scale during the Eighteenth Century was practically unknown. In the early part of the Nineteenth Century, cast iron was largely used for bridges, for canal aqueducts, for locks, and for dozens of other purposes, only to be supplanted in its turn by wrought iron. When this metal could be obtained cheaply and abundantly, engineering entered upon a new phase of its existence, and the world commenced to progress at a speed hitherto undreamed of.

It was under conditions such as these that the subject of this memoir entered his professional career. He was born in 1817 at Wadsley Hall, Sheffield, the residence of his father, Mr. John Fowler, and when his general education was completed the boy, at the age of seventeen, became the pupil of Mr. J. T. Leather, the well-known hydraulic engineer. Here he had ample facilities for obtaining a thorough training in several branches of his calling, and in all cases his experience was gained in works of very considerable magnitude. Yorkshire enjoys the advantage of possessing a great number of diverse industries, and it was very early in the field as a

manufacturing district. The county was thus able to find employment for many engineers, and among them Mr. Leather took a leading position.

When Mr. Fowler left Mr. Leather, the railway mania had commenced, and he went straight into the railway world, finding in the office of Mr. J. U. Rastrick a very wide field. He became his chief assistant in the preparation and contracts for several railways; among these was the line from London to Brighton. To this latter Mr. Fowler gave great attention, and there is scarcely a bridge or viaduct which was not personally worked out by him. After two years spent in London, he returned to Mr. Leather, and became responsible resident engineer of the Stockton and Hartlepool Railway. After it was completed he remained two years as engineer, general manager, and locomotive superintendent of that and the Clarence Railway.

On the termination of this engagement, Mr. Fowler visited, at the invitation of Sir John Macneil, several railways in the neighborhood of Glasgow, and gave evidence before Parliamentary committees regarding them. He commenced an independent career at the age of twenty-six, and, as we have already seen, he started with a broad and solid foundation of experience, suitable for the towering reputation which was to be built upon it. Several important railways were then being promoted from Sheffield, such as the Sheffield and Lincolnshire, the Great Grimsby, the New Holland, the East Lincolnshire, and others, and of these Mr. Fowler became the chief engineer, conducting them through Parliament and carrying them out.

Mr. Fowler had now attained a position which necessitated his permanent residence in the metropolis, and work of all kinds flowed in to him. It is quite beyond the limits of our space to notice, much less to describe, one half of the matters about which he was consulted, or the works he carried out. Among them we may mention the following: The Oxford, Worcester, and Wolverhampton Railways; the Severn Valley Railway; the London, Tilbury and Southend Railway (in conjunction with Mr. Bidder); the Liverpool Central Station; the Northern and Western Railway of Ireland; the railways of New South Wales and India; the Sheffield and Glasgow waterworks; the Metropolitan Inner Circle Railway; the St. John's Wood Railway; the Hammersmith Railway; the Highgate and Midland Railway; the Victoria Bridge and Pimlico Railway; the Glasgow Union and City Railway, and St. Enoch's Station; the Millwall Docks; the Channel Ferry, and many others.

Mr. Fowler's reputation with the general public of this generation rests to a great degree on his construction of the Metropolitan Railways. These were so far out of the common that every Londoner, and a great many people out of London, took the greatest interest in them.

The construction of the so-called Underground Railway was the means of solving a great many problems which at the time presented much difficulty. Questions which are now fully understood, and which would be undertaken by contractors as a mere matter of course, then were of very grave importance, and had not only to be exhaustively discussed, but to be attacked with the greatest caution.

Mr. Fowler was elected President of the Institution of Civil Engineers for the year 1866, and took the chair for the first time in that capacity on

FORTH BRIDGE—GENERAL VIEW.

January 9th. His presidential address was devoted to the subject of the education of an engineer, and was so important and valuable that it has been reprinted and distributed extensively, notably by the Government of India to the engineers in its employment.

In 1870 he was a member of a commission to examine the railways of Norway, with reference to the proper gauge to adopt for the railways of India, and he made decided recommendations regarding it. During the winter of 1888-9 he had the opportunity of verifying by actual inspection on the spot the opinion he had formed as to the railway policy of India, and it is well known that he has expressed himself as having had his former conclusions strongly confirmed by his Indian visit. He was naturally much consulted, both professionally and otherwise, in India by the authorities on the subject of railways, docks, and waterworks, and was received everywhere with great distinction. His general impressions of India and its resources were of the most favorable character.

One of the most interesting chapters in Mr. Fowler's career is that connected with Egypt. He went there in the first instance in search of health; and the connection thus accidentally formed lasted as long as Ismail Pasha remained in power. Before Mr. Fowler returned home he had several interviews with the Khedive, explaining to him his views concerning the Suez Canal, the irrigation schemes, and many other matters in which Ismail Pasha was interested. The outcome of this was that he accepted the position of consulting engineer to the Khedive and the Egyptian Government, a post which he held for eight years—that is, until the abdication of that ruler. The office involved yearly journeys to Egypt, the first being in the latter part of 1871, and required Mr. Fowler to personally investigate all the great undertakings then in hand. The most important matter presented to him for solution was the projected Soudan Railway. It is needless to say that, although commenced, and 150 miles constructed, it was never carried out, or recent Egyptian history would have been greatly changed, while thousands of British soldiers and millions of money would have been saved.

One of the first matters claiming his attention on undertaking the duties of consulting engineer was the organization of the existing railways, and to this he devoted much time on his first official visit. As a preliminary he employed Mr. D. K. Clark to obtain for him full details of the rolling stock and plant. With this information before him, he was able to advise great changes in the direction of simplicity and economy, most of which were carried out.

Another important matter presented to him was that of irrigation. Upon this depends to a great extent the fertility of Lower Egypt, for although the annual inundations can be depended upon to give the land one thorough watering, there are many crops that need to be watered several times, and at different seasons of the year from that at which the flood comes. Under the existing conditions, Mr. Fowler was instructed (1) to prepare alternative plans for placing all the cultivated and cultivable lands of Lower Egypt in a position to be irrigated at any time of the year without pumping; (2) to devise an improved means of introducing flood water several times during high Nile upon any required lands on the left bank of the Nile, and of discharging it at pleasure without interference with other lands; (3) to prepare a scheme for a ship canal between Alexandria and Cairo.

We come now to the Forth Bridge, the best known of all the works with which Sir John Fowler was associated, and one which has engaged the attention both of the general public and of engineering experts in all parts of the world. The design was not his alone, but was the joint outcome of four minds, all bent on discovering the best and cheapest means for carrying a railway over the Firth of Forth. When the Tay bridge was destroyed preparations were being made, and were actually commenced, for bridging the Forth. Sir Thomas Bouch had designed a suspension bridge for the purpose, and an Act of Parliament had been obtained authorizing its construction. The failure of the Tay bridge at once threw doubts upon the safety of this most ambitious project, and the works were stopped. Subsequent investigation showed that the proposed bridge could not have been a satisfactory one.

A bridge across the Forth offered so much advantage to the railway companies forming the east coast route to Scotland that, after two years, the idea was revived. On February 18, 1881, the four great railway companies concerned, the Great Northern, the North Eastern, the Midland, and the North British, wrote to their consulting engineers—Mr. T. Harrison, Mr. W. H. Barlow, and Mr. John Fowler, associated with Mr. B. Baker—propounding two questions for their joint opinions. They were asked to consider the feasibility of building a bridge for railway purposes across the Forth, and, assuming the feasibility to be proved, what description of bridge would be most desirable to adopt. The matter involved so large an expenditure and contained so many novel issues that it needed to be approached with the greatest possible care. It was fairly well known how many types of bridge there were to select from for such a site—(1) Mr. Bouch's original design, (2) a stiffened suspension bridge, (3) a second form of stiffened suspension bridge, (4) a cantilever bridge. Calculations of weight and cost were made for each type of bridge, and were discussed by Messrs. Harrison, Barlow, Fowler, and Baker, with the general result that the cantilever type was chosen. A report was made to the railway companies on May 4, 1881, embodying the result of the deliberations, and pointing out that the cantilever principle offered a cheaper and better solution of the problem than any other. The report did not enter into the details of construction; indeed, it could not be said to give even the broad features, other than those which are involved in the use of the cantilever. These still remained to be elaborated in council, and it was only by united discussion that the original plan developed into the final design. Although the type of the bridge is very ancient, there were many features in it which were open to consideration, and to differences of opinion, and at each meeting of the engineers new ideas were propounded and novel methods of overcoming difficulties were mooted. After most elaborate investigations and calculations the structure gradually, by a process of evolution or development, assumed its present form.

The design being settled and the execution decided upon by the associated railway companies, the carrying out of the work was intrusted to Mr. Fowler, in conjunction with his partner, Mr. Benjamin Baker.

The Parliamentary fight was exceedingly stubborn, for great interests were at stake. Hitherto the London and Northwestern and the Caledonian companies had enjoyed a great advantage in carrying the Scotch traffic to

FORTH BRIDGE—LOOKING ACROSS THE BRIDGE.

Perth and the Highlands, in consequence of the east coast traffic having to traverse the circuit from Edinburgh via Larbert and Sterling to Perth. But when the bridge was opened this advantage disappeared. A very strong hybrid semi-public committee was appointed, with Lord Stanley, of Preston, and later Governor of Canada, as the chairman. Engineering evidence was brought forward to condemn the structure, and every possible description of hostile evidence for shipping interests was adduced against it, and made the most of by eminent counsel, who both in speeches and cross-examination strove to the utmost to prejudice the undertaking. But at the close of the case the committee were unanimous in favor of the bill, only stipulating that the Board of Trade should maintain a general inspection of the works during construction. It was finally arranged, at the suggestion of Mr. Fowler, that the inspectors should report to Parliament every three months as to the progress of the bridge, and the quality of the materials and workmanship. These reports, made by General Hutchinson and Major Marindin, made their appearance regularly. Sir John Fowler and Mr. Baker kept a personal and continuous control over the entire operation of building the bridge, and have superintended the series of processes, from the rolling of the plates to the driving of the rivets.

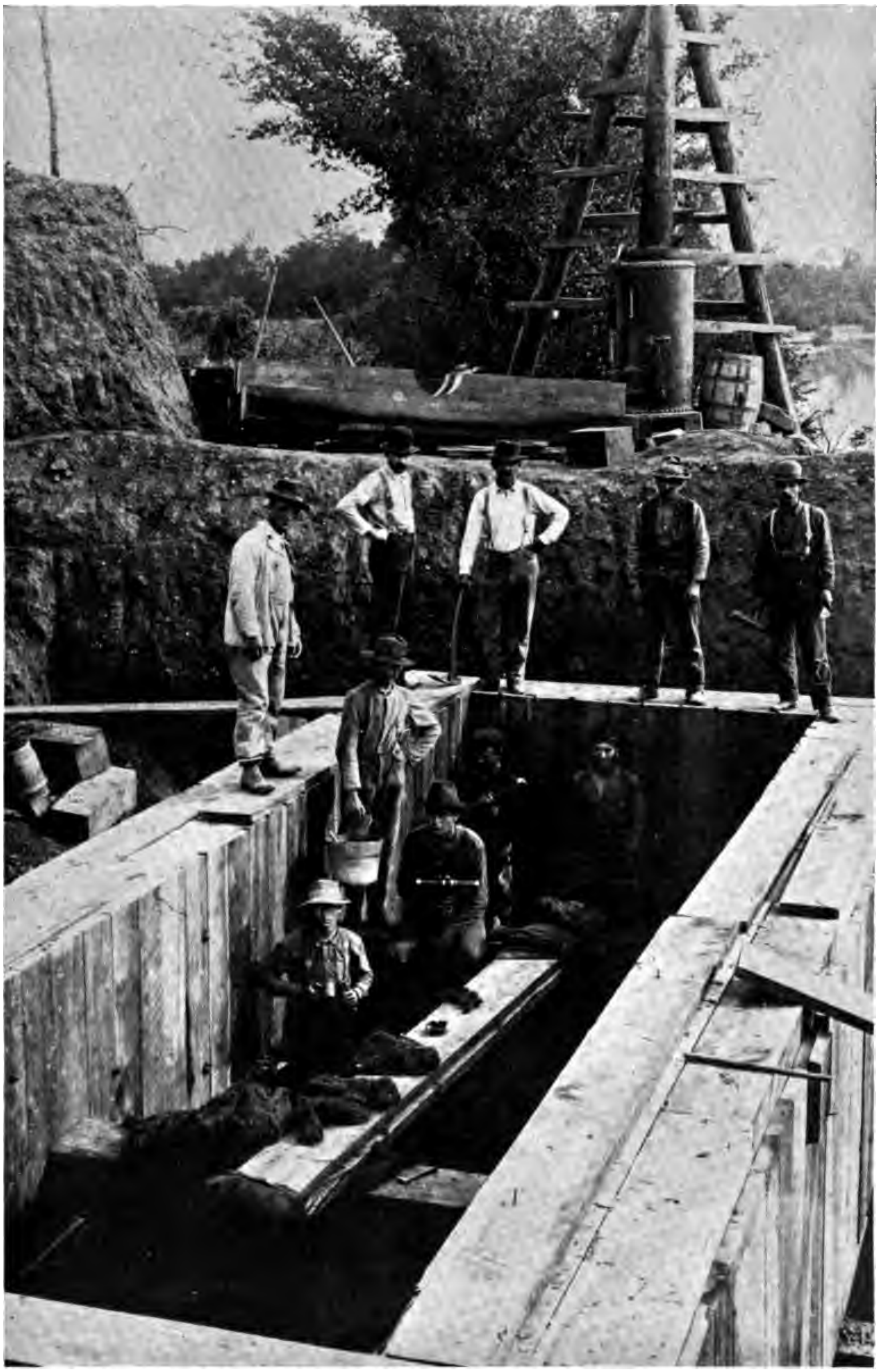
The bridge consists of two approach viaducts and the cantilever bridge proper. The viaducts only differ in extent; the height above the water and the lengths of the spans being the same. It will be seen that a similar viaduct or permanent way is carried through the cantilevers and central towers at one uniform level. Commencing at the south end there are four granite masonry arches, which terminate in the abutment for the south approach viaduct. Here the girder spans commence—ten in number—the end of the last being supported in the south cantilever end pier. On the north shore there are three similar masonry arches, terminating in an abutment, and five girder spans to the north cantilever end pier.

The bridge proper consists of three double cantilevers and two central connecting girders. Each double cantilever consists of a central tower supported on four circular masonry piers—a cantilever projecting from each side of it. The two outside piers—the Fife and Queensferry—have, in addition to the four supports of their central towers, a further support, inasmuch as their outer cantilevers rest in the cantilever end piers. No such additional support was available in the case of the Inchgarvie pier, and the length of the base has here been nearly doubled. The length of the cantilever bridge is 5,330 feet, consisting of the central tower on Inchgarvie, 260 feet; the Fife and Queensferry central towers, 145 feet each; the two central connecting girders, 350 feet each, and six cantilevers of 680 feet each. The cantilever end piers are 5,349 feet six inches apart, center to center. The south approach viaduct is 1,978 feet long from center of cantilever end pier to end of arches, consisting of ten spans of 168 feet each, four arches of sixty-six feet each, center to center, and thirty-four feet made up by abutments. The north approach viaduct is 968 feet three and one-half inches long to end of arches, consisting of five spans of 168 feet each, three arches of thirty-seven feet, thirty-one feet, and forty-six feet, center to center, respectively, and fourteen feet three and one-half inches, made up by abutments. The total length of the structure is, therefore, 8,295 feet nine and one-half inches. The two main spans are 1,710 feet

PNEUMATIC CAISSONS FOR ORDINARY FOUNDATIONS

AT many places on our larger rivers it is so difficult to get first-class foundations, and keep other than first-class ones after once put in, that the only really safe way is to employ pneumatic caissons. For the ordinary large highway bridge as built by county or city, this is seldom considered, owing to the fact that comparatively very few officials having charge of this work know anything of pneumatic foundations, and until recently such work has been too expensive for bridges of this class. Pneumatic work has been made much cheaper by competition and skillful handling, until for large highway bridges where good foundations are hard to get it is not only the best method, but almost as cheap as pile foundations. When the pneumatic caisson foundation is completed there is no question as to its stability, and no future expense for protection to hold it. A well-built bridge on this foundation is for the use of generations to come, and, unlike many bridges on other foundations, will not need replacing before the present generation has passed away.

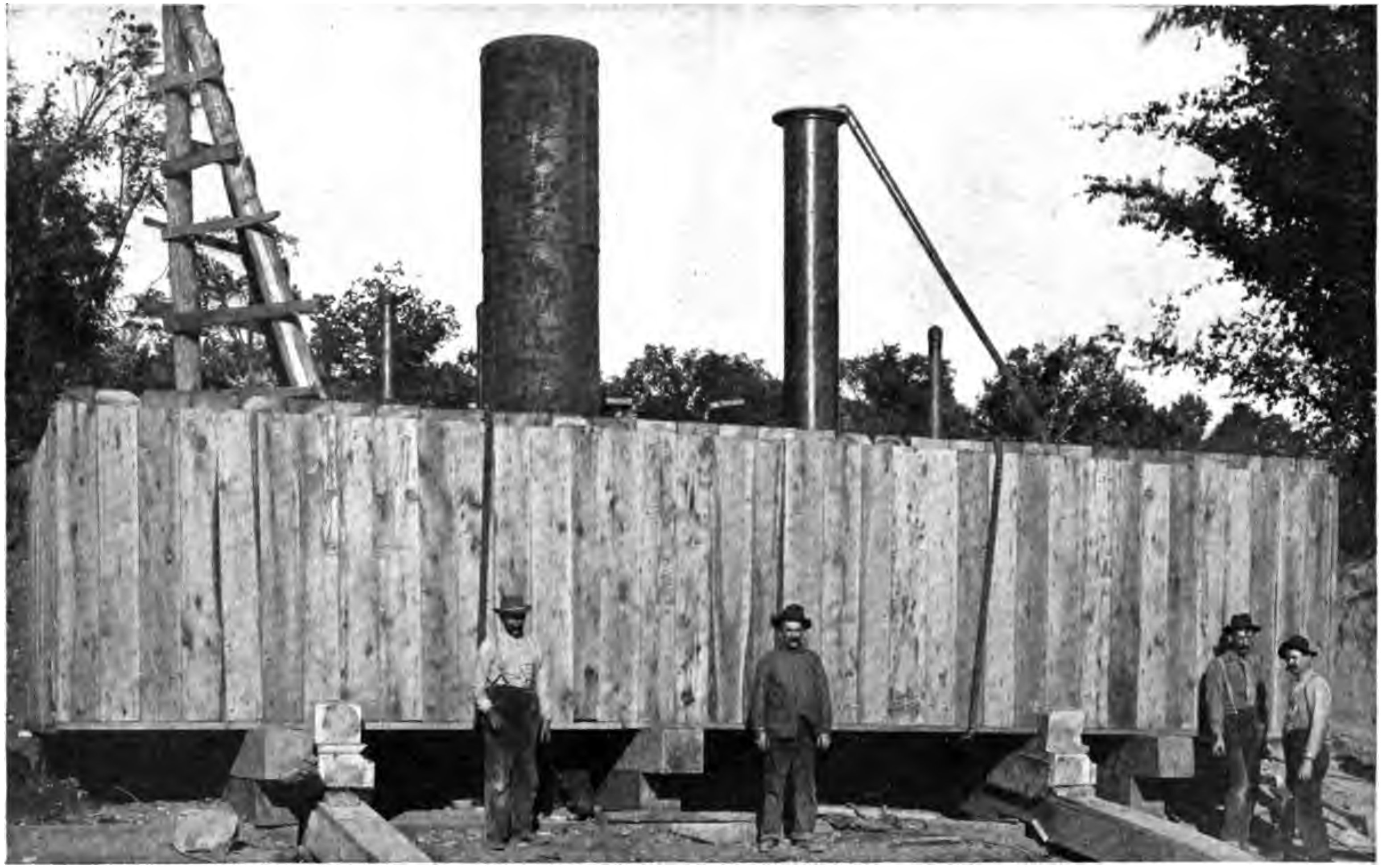
A recent experience with a bridge on the Scioto River is a good example of pneumatic work for highway bridges. In 1871 the County Commissioners of Ross County, Ohio, built a bridge across the Scioto River at the old ford at the foot of Main Street, Chillicothe. At that time on the west side, next to town, there was a side pass in which there was water whenever the river was above an ordinary stage; then to the east an island, about six hundred feet wide, and the main channel, about four hundred feet wide. The bridge was constructed in four spans of covered and weather-boarded Howe truss, each span being 154 feet long. Two abutments were built, and one span put across the side pass, while two abutments and two piers were built, and three spans were placed across the main channel. A fill was made across the island twenty-four feet wide on top and level with the bridge floor, and the whole of both slopes riprapped for over five hundred feet. The piers and abutments were of heavy masonry, built of freestone rock quarried in Ross County, the foundations for which were timber platforms setting on the sand and gravel of the river bottom. Wherever the river was less than four or five feet deep, holes for the platforms were scraped out with ordinary drag scrapers, pulled by mules, the scraping being continued until the water was too deep for the mules to work. Around the foundations thus constructed, piles were driven twelve to fourteen feet in the ground, and the space between the masonry and piles filled in with loose rock. The bridge stood thus for over twenty years, although some of the low part of the east fill had been washed out a few times. In the winter of 1893 the protection was washed away from the east pier, and the foundation undermined, so a portion of the pier soon fell down, but enough remained to hold the bridge. In the summer of 1893 an entire new pier was built, the ends of the old spans being held up by false work while the old pier was taken out and a new one erected at a cost of $8,000. The new foundation consisted of forty-two piles, driven to about twenty feet below low water, until most of them were hard to drive, and cut off six



CALKING CAISSON NO. 2.

feet below low water. A heavy timber platform was then drift-bolted to the piles, and on this platform was constructed a pier of first-class masonry. Around the pier was also placed a protection of piles and loose rock. On the night before Christmas, 1895, the three-span part of the bridge was completely burned, leaving a charred ruin in the river and the masonry badly cracked. It was then decided to repair the masonry and build an iron bridge. The masonry was repaired by tearing down and rebuilding all that was cracked by fire, which was several feet of the top of each abutment and the west pier, and almost the entire east pier above the water line. From the 10th to the 20th of March, 1898, was a continuation of wet weather in the whole Scioto Valley, followed on the 20th to 22d by very heavy rains, especially in the upper water-shed, where the swamps and lowlands had been cleared and thoroughly drained in recent years. The result was a rapid rise in the Scioto River, the high water reaching a stage three or four feet above the height of any previous flood, and no railway or highway bridge from Columbus to the Ohio River was able to carry all the water. The Main Street bridge had one of the narrowest water-ways on the river, only about five hundred and seventy feet total clearance, and no way for much water to get around. On the 24th of March the bridge over the main channel was washed out, the east abutment, both piers, and the three spans of new iron bridge going down. The west span was floated around onto a bank that is ten or twelve feet above low water, and remained in sight, but the abutment, both piers, and the other two spans disappeared as if swallowed up in a whirlpool, and no trace of them was seen for weeks, until the water had reached an ordinary stage; and indeed to this day all we have ever found of the east pier was a couple of piles high and dry in a cornfield, and three or four coping stone thirty feet below low water, while sinking the pneumatic caisson.

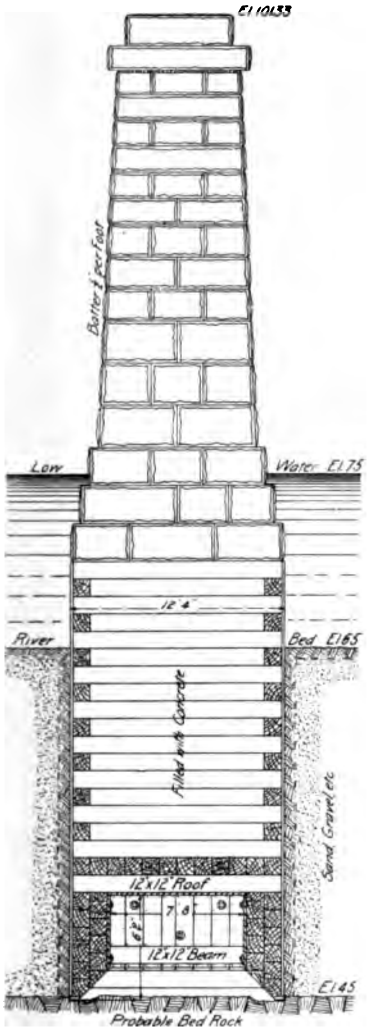
It was several weeks before the water reached a stage that any work could be done toward examining the bottom of the river or making soundings. It was eventually decided to rebuild and to make two spans across the main channel, with one old span repaired as an eastern approach. To place the pier on the east side far enough back so there would be no probability, in putting it down, of striking any part of the old abutment foundation that might remain, required the two spans to be 242 feet each. Soundings were then made to ascertain how far below low water it would be necessary to go to reach solid slate or rock. A point was procured from a well-driver, and with an abundance of 1¼-inch pipe and fittings a pipe was driven at several places within the location of the pier. A ten-pound sledge was used for driving, and was heavy enough to send the rod down and burst the couplings when the rock was struck. Evidently there were many rocks below the river bed, as the pipe frequently slipped to one side or refused to go, and had to be withdrawn, and at a depth of twenty-eight to thirty feet below low water at a couple of different places would go no further, and we felt safe in counting on a solid bottom at that depth. Nevertheless it was thought possible that we might be on quicksand, and concluded to try and verify the sounding by sinking a pipe with a water jet, and accordingly an old-fashioned fire engine was procured from the fire department and the hose fitted to a T on top of the pipe; a head to pound on being above the hose connection. This apparatus was not much



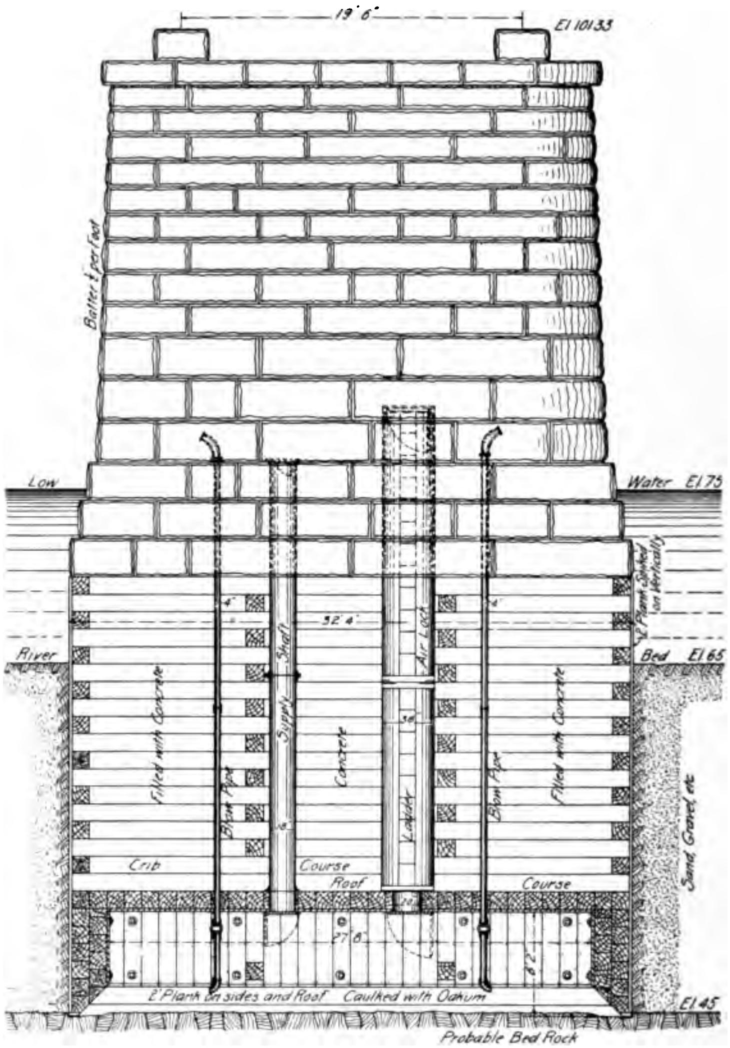
CAISSON NO. 1 ON RUNWAYS.

of a success, and we reached only to about the same depth as previously driven. It proved, though, that there were coarse gravel strata below the river bed, which allowed the water to escape from the bottom, without making a way for the pipe. A well-driller with his apparatus was set to work at site of pier No. 2, and started down a six-inch pipe. At about twenty-two feet below low water he reported that he had struck slate, and was notified to wait until someone could inspect the work, and then drill five feet into slate. There proved to be some slate drillings, and the tools were fast in the pipe. He was paid for the work already done, that he might procure other tools or rescue the ones already lost, but the well-driller disappeared to parts unknown, and his entire outfit still stands just north of our new pier. It was now about time for awarding the contracts, and no time to try other methods of sounding. It was decided that any form of pile foundation would be unsafe, for it had been demonstrated that piles which were with difficulty driven to twenty feet below low water were not deep enough to prevent undermining, and the more protection put around the pier the greater the tendency to scour. Proposals were asked for different forms of foundations for two piers, especially for elliptical steel shells filled with concrete, circular tubes filled with concrete, and solid stone work to thirty and twenty-four feet, respectively, below low water. Bids upon pneumatic work was not especially requested, as it was supposed that such work would be entirely too expensive for the funds at the disposal of the county. Bids were received on July 19, 1898, for six different forms of foundations, as follows, the amounts given being the total amount for the two piers complete to thirty and twenty-four feet below low water: For two eight-foot tubes for center pier and two seven-foot tubes for east pier, tubes to be filled with concrete and joined together, a bid of $6,210 was received; for oblong steel shells thirty-two feet long and eleven feet and ten feet six inches wide, respectively, $10,830; for a special design of tubular piers, in which the portions below low water were ten feet in diameter, $9,167; for solid stone piers, founded on slate by means of cofferdams, $13,225; and for pneumatic caisson foundation, with crib of timber filled with concrete to within five feet of low water and masonry from this to bridge seat, Willard & Cornwell bid $10,900, if Louisville cement were used; $11,215 if Rosendale cement were used, and $11,550 if Portland cement were used. These bids were for piers Nos. 1 and 2 only.

It had been with great difficulty that all previous foundations for Scioto River bridges in Ross County had been put in by use of cofferdams, owing to the river gravel being very coarse and full of bowlders, and taking this into consideration it was decided to adopt the pneumatic foundations, as being the surest and safest plan, and certain to reach bed-rock no matter what might be encountered. A few days after bids were received, the contract was awarded to Willard & Cornwell to construct two masonry piers on pneumatic caisson foundations with crib filled with concrete to within five feet of low water, according to plan shown. On August 12th work was begun on setting up the air-compressor and getting ready for caisson No. 1. The contractors' plant for this work consisted of a double compressor with cylinders 14x16x18 inches, run by a boiler of locomotive type capable of generating 120-horse power; a 115-volt dynamo of nine amperes capacity, run by a vertical engine supplied with steam from the big boiler:



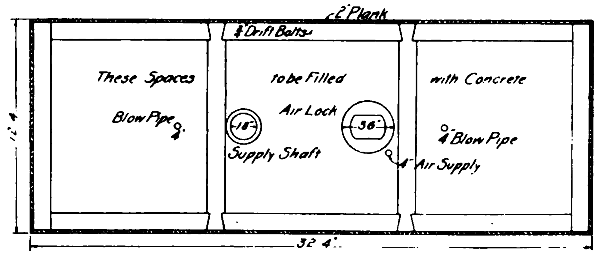
—End Section—



—Longitudinal Section—

..*Plan for Sub-Structure*..
—OF—
Main St. Bridge, Scioto River
Chillicothe, Ohio.

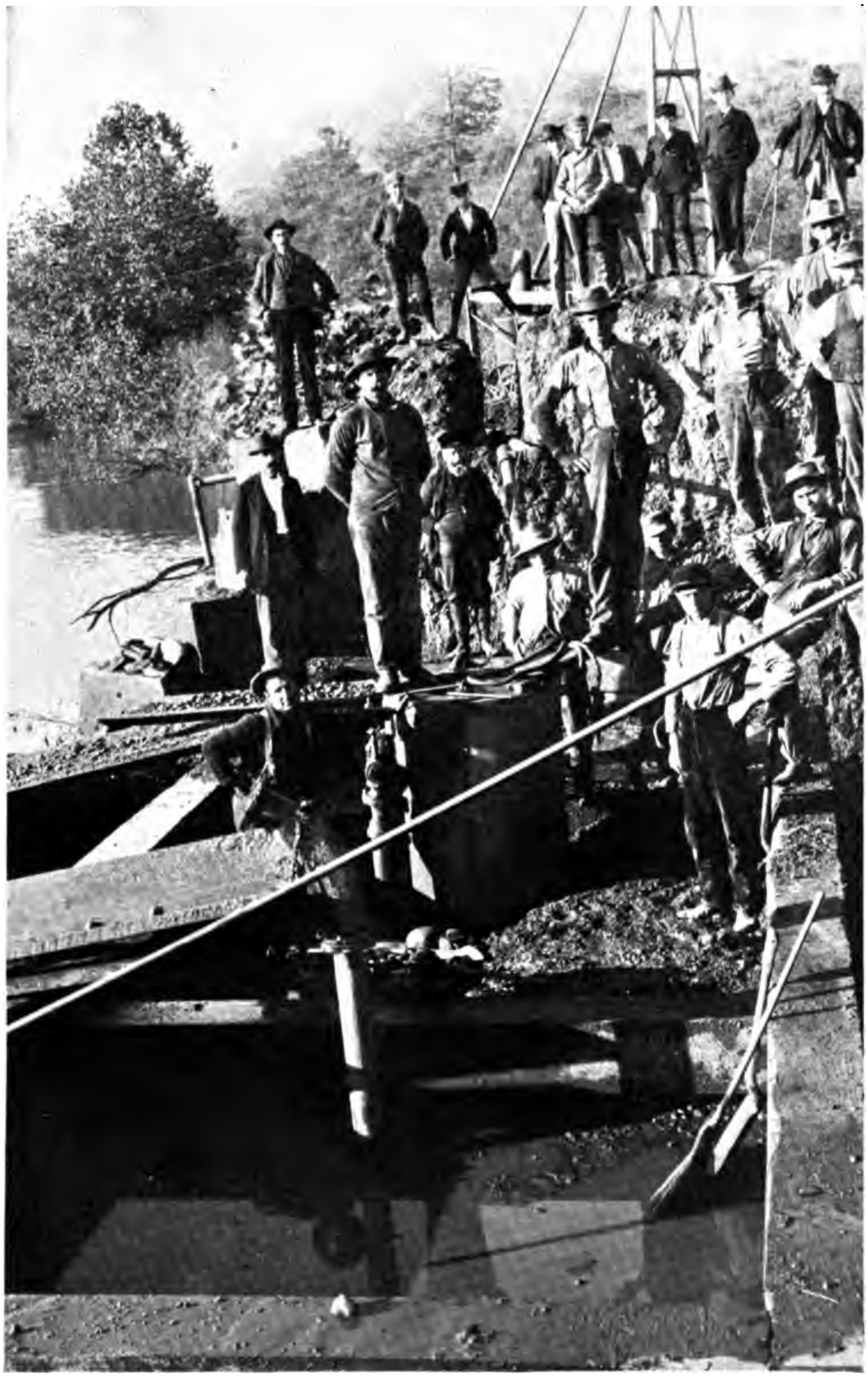
—Gregg D Wolfe Del 93—



—Plan of Crib—

an air receiver fifty-six inches in diameter and fifteen feet long, and all necessary pumps, pipes, connections, fittings, etc., with hoisting engines, derricks, mortar boxes, tools and everything necessary for heavy masonry and concrete work. The compressor and boiler were set up on the solid roadbed, a few feet west of the old abutment, the compressor being next to the abutment, the boiler immediately west, and the dynamo and engine, for generating electricity for lighting the caisson, engine-house and office being in the same building and just south of the compressor and boiler, the whole being covered by a substantial frame shed eighteen feet by thirty-six feet. An office, ten feet by twelve feet, adjoins this building on the east. The receiver was placed north of the compressor, on the edge of the fill. A driven well at the foot of the embankment on this side, with a force pump, supplies water for the boiler and drinking water for the men. An eight-inch natural gas main runs within 1,000 feet of the engine-house, and an inch pipe was laid from it and connected to the boiler to supply fuel for generating steam.

Both caissons were built exactly according to plan, twelve feet wide by thirty-two feet long and six feet deep inside, and sheeted inside and out with two-inch plank. The sides and roof of the caisson are two feet thick, built of 12x12-inch timber, each course being fastened to the courses below with ¾ and ⅞ inch drift bolts, thirty inches long and placed four or five feet apart. The two courses of the sides and ends are firmly fastened together by two rows of ⅞-inch bolts extending clear through both. The two bottom layers of timber are beveled off on the inside until only about four inches wide at the bottom, and on the bottom a 2x6-inch plank is firmly spiked, forming the "cutting edge" of the caisson. Two 12x12-inch tie-beams are dovetailed into the sides of the caisson, thus dividing the inside into three equal "pockets." There are five holes through the roof, a four-inch hole at the center of each end "pocket" for the blow-out pipes; in the middle pocket an eighteen-inch hole near one beam and a twenty-inch hole near the other beam for the supply pipe and air shaft, respectively, with a four-inch hole near the latter for the air supply pipe. When one course of the roof is placed, the shafts are fastened on by means of bolts through this course and the flanges of the shafts. The air shaft is thirty-six inches in diameter, of the best ¼-inch boiler iron, thoroughly riveted together at the lap joints and to inside flanges of 1½-inch cast iron at each end, each flange having twenty-eight ¾-inch holes for bolts to fasten joints together. The flanges are on the inside, so they can be used for the lock doors to fit against, and the bolts being on the inside can be removed and the top sections of the pipe taken out when pneumatic work is finished. The supply pipe is eighteen inches in diameter, of the same material as the air shaft, and 3-16-inch thick. It is riveted together the same as the air shaft, except that the cast flange is on the outside and has but eighteen holes for bolts. These shafts are in joints varying from nine to fifteen feet in length. The timber used in caisson walls in crib and outside sheeting may be any good round timber in lengths of ten to twenty-four feet. In this work hickory, lynn, sycamore, red oak, etc., were used for all work except inside sheeting, which was of dressed pine. The inside of the caisson, from the cutting edge to the roof, and all over the roof, was calked carefully in each joint between the timbers and around



CAISSON NO. 2 PARTLY CONCRETED.

all bolt heads, then sheeted from bevel edge to roof and overhead, every joint of the sheeting being thoroughly calked. Caisson No. 1, which was to go in the middle of the river, was built on timber runways on the bank, arranged so they could be raised at one end and slide the caisson off into the water when it should be ready to launch. Two heavy ropes were placed around the caisson and tied to posts behind, the runways were covered with soft soap, and the ends raised until the caisson was started and held only by the ropes, which were cut simultaneously, and the caisson slid out into deep water and floated with the top but little above the surface. On September 8th it was launched, towed into position, and anchored by ropes leading to some old piles at one side, and to a heavy anchor and a piece of old bridge iron up stream. When launched, but one course of roof or decking had been put on, and as soon as anchored to place the other course was put on and the crib on top built up several feet. This cribbing is of 12x12-inch timbers, laid so as to make the outside of crib twelve feet by thirty-two feet, every other course tied together by two 12x12-inch cross ties dovetailed in, and the whole fastened together with thirty-inch drift bolts every four or five feet. The sheeting is also carried up continuous on the outside from the cutting edge. The top of the decking was then thoroughly grouted, the crib filled with concrete to the height of several feet, until the "cutting edge" rested on the river bottom and the top was four or five feet above water. This concrete was composed of one part Portland cement, two and one-half parts sand, and five parts gravel, with a good many large bowlders bedded in each layer. A three-inch pipe was laid from the receiver down the bank and along the river bed to the pier, and connected to the air supply pipe by a double flexible pipe joint. At noon of September 12th air was turned on and the work of sinking was carried on day and night by two crews, each working ten hours. Each crew of "sand hogs," as the men engaged in this work are called, consists of a foreman, two blow-pipe feeders, four shovelers, an inside lock-tender, and an outside lock-tender. The working chamber is lighted with three sixteen-candle power electric lights, and there is one in each section of the air shaft. The blow-out pipes just below the roof of the caisson are fitted with large valves with a four-inch opening. A piece of pipe from the valve extends to the bottom of the caisson, and when the valve is opened all sand, gravel and rock less than four inches in diameter brought up to the end of the pipe is forced out by the air pressure. On the top of each blow-out pipe is fastened a "goose neck," a curved joint to turn the material away from the crib. This "goose neck" is cast iron, with a four-inch opening and heavy walls, especially on the upper side where the gravel strikes, for it comes out with such force that an ordinary pipe bent to a curve would last but a few hours. All rock too large to blow out through the pipes is "locked" out through the air shaft in sacks. To sink the caisson all material is cleaned out level with the "cutting edge," then it is "ditched" by shoveling several inches of material from under the "cutting edge" and given a "blow" by opening one of the valves and letting out the greater part of the air. Relieved of the lift of the compressed air, and with the weight of concrete on top, the caisson settles down from six to ten inches, or until the cutting edge is again on solid gravel. While the air is escaping the working chamber is filling with water, and will frequently be two-thirds

SETTING FOOTING COURSES PIER NO. 2.

full when done "blowing." Caisson No. 1, for eighteen or twenty feet below the bed of the river, went down smoothly and rapidly without delay. At this depth was encountered a layer of bowlders varying in weight from five pounds to over one hundred pounds, and at the bottom of the layer were three coping stones from the top of the old east pier, which had been washed out. These stones were thirty feet below low water and sixty-six feet from where the pier had stood, showing how deep the scour had been when the water was highest. As the water fell and the current became less swift, the larger rock coming down were deposited, and then the smaller rock, gravel and sand. This layer of rock was what had stopped the sounding rod, but immediately below was six or eight feet of quicksand, and then another layer of gravel and rocks, but bed rock was not struck until forty-three feet below low water. The bed rock consisted of black shale and limestone in alternating layers of about two inches in thickness. The caisson was landed and rock leveled down after twenty-three days work, and on the morning of October 6th concreting the air chamber was begun. To concrete the air chamber a two-inch pipe conection is made from the air pipe to a point just below the top flange of the supply pipe. This pipe has a valve, No. 1, near the air pipe, and another valve, No. 2, on a T between valve No. 1 and the supply shaft. A top door opening down is then put on the supply shaft and the fastening taken off the lower door. A batch of concrete is shoveled into the supply pipe, the upper door pulled up, valve No. 2 closed and No. 1 opened. This puts compressed air in the supply shaft, and allows the lower door to equalize open and the concrete falls into the working chamber, where it is rammed under the bevel edges and over the bottom by the "sand hogs." The lower door is then shut, valve No. 1 closed, and No. 2 opened, allowing the compressed air in the supply shaft to equalize out and the top door opens. The process is repeated until the chamber is filled with concrete and barely a narrow passageway for one man is left between the lower doors of the supply shaft and air shaft. The lower doors are then shut, and the last man equalizes out. A regular air pressure is then kept on for twelve or eighteen hours, until the concrete sets. The air is then turned off, and the shafts filled with concrete as quickly as possible. As soon as the air pressure is taken off the lower doors drop and the space left in the working chamber is also filled with concrete, which runs in from the shafts. This finishes the foundation from bed rock to above low water.

Caisson No. 2 was built about ten feet back of the washed-out abutment, part of the old approach being leveled down to near low water mark so it could be built exactly where it was to sink, and at noon of the 14th day of October air was put on caisson No. 2. This caisson was above the water level, and before putting on air it had been sunk about two feet. As the pressure at first would be low, temporary blow-pipes were put in the side near the roof, and used to blow out sand and gravel until they were down to water level. This required less air to blow out material than to lift it through the roof. When down to water level these pipes were removed and the holes plugged. This caisson went down without special incident until the "cutting edge" was about fifteen feet below low water, when a good sized red oak tree was encountered. Several blasts were put into holes bored in the tree under the cutting edge, until the trunk was

severed at this point. The tree was then sawed up and removed through the air locks. Dynamite was used to blast out this tree, and also to blast to pieces large stone found in the caissons. When blasting the men stayed in the air shaft, and frequently in the working chamber itself, for the concussion from a blast is not felt under air pressure as it would be on the outside. Test rods were driven at several points inside, and there was apparently a level bed rock about twenty feet below low water. Accordingly on October 8th the cutting edge being about five feet from the bottom

CAISSON NO. 3 READY TO SINK.

of the rods, the first footing course was laid and the next day the second course offset six inches all around, making it 11x31 feet. According to the rods we were then about two and one-half feet from bed rock. The "sand hogs" now attempted to pull the ⅞-inch sounding rods which had been cut off as the caisson was sunk, and found they could not move them, although but two and one-half feet were in the ground. They even broke a large chain by using leverage to pull on the rods—we then had them dig down at one point, and they brought up a sample of a peculiar material that was neither peat nor lignite, although it was evidently the bottom of

an old swamp. The material was tough and like rubber when a pointed rod was driven into it, but a piece taken out proved to be brittle and of no strength. We now drove rods through it and found that after two or three feet they again drove part of the way, with great ease, until striking bed rock on a level with bed rock under caisson No. 1. It was decided not to land the caisson on the lignitic peat, as there was evidently quicksand under this layer, and the sinking was continued. This material was hard to work, and the "sand hogs" were seven days making two feet in depth. The first course of stone, and part of the second, was below water before it was decided to continue, and therefore the 11x31 feet of masonry had to be brought on up. A great many difficulties were encountered in sinking this last twenty-two feet, and it was not completed until November 30th. The compressor broke down twice, and high water got above the masonry and stopped the work once for several days. The first footing course dragged considerable, and held back the caisson in sinking, and the ends at different times were as much as a foot out of level. In bringing the pier back to a level several of the joints in the masonry were opened, but no stone cracked. Below this lignitic peat the sand and gravel was of a different character than that above or what was encountered in sinking caisson No. 1. First there was eight or ten feet of sand almost as fine as quicksand, and working like quicksand, then the rest was coarse gravel with bowlders. This sand and gravel was dark, but contained but little soil, the color being given by hornblende and other dark rock in the drift. Within a foot of the bed rock was found a skull, which proved to be that of a pre-glacial hog. The lignitic peat is a formation of the glacial period.

Pier No. 3 was to be erected 154 feet east of the river, to hold the end of an approach span which was to take the place of that much embankment. One of the spans of the old bridge was repaired for this approach, and it was originally intended to use four-foot tubes sunk to solid foundation to hold the east end, but when bids were received the bid of $2,900 was made for a pneumatic caisson sunk to twenty feet below low water, with masonry pier. The bids for the tubes were from $1,012 to $2,200, and the Commissioners at first awarded the contract to the lowest bidder on tubes, but within three weeks the sinking of caisson No. 2 proved what difficulties might be encountered in sinking tubes and possibly result in failure, and the bidder on tubes willingly consenting, the contract for pneumatic caisson was awarded to the contractor who was building the other two. This caisson was built ten feet four inches by twenty-seven feet four inches on the outside, with walls of 10x12-inch timbers, making the inside twenty-three feet eight inches by six feet eight inches. Temporary blow-pipes near the roof were also used in sinking caisson No. 3, this time being placed in the ends. On December 12th air was turned on No. 3, and it was sunk through a layer of drift gravel, a layer of loose rocks, and a layer of quicksand, and landed on the lignitic peat nineteen feet below low water, and the concreting was completed on December 28th. High water delayed work on this caisson four days, breaking the air pipe in the middle of the river. This completed the pneumatic work, and the masonry, having been kept up pretty closely, was completed on January 6, 1899. All masonry work was of heavy freestone rock from Otway, near the Ohio River, in Scioto County. Three thicknesses,

seventeen inches, twenty-one inches, and twenty-eight inches, were used. The masonry was quarry-faced, with full dressed beds and laid in Portland cement mortar mixed in proportion of one part cement to two parts sand. No grouting was used except in holes too small to ram concrete in, the backing being of stone placed far enough apart to allow concrete to be rammed in solidly between. Piers No. 1 and No. 2 are shown in the plan while pier No. 3 was lighter, being but twenty-four feet long by five feet three inches wide under the coping, and built with square ends. It being in place of an abutment, the earth fill is given a natural slope at the ends and in front of the masonry.

Many persons were allowed to go down in the caissons to see the process of working. For the trip they were fitted out with overalls, jacket, an old

FLASHLIGHT IN CAISSON.

hat and rubber boots. The top door of the air-lock or shaft had a rope fastened in the ring to handle it by when the air was off. When the door was closed and the air pressure on several tons would be required to open it by force, but as soon as the signal was given—five taps with the hammer by the outside lock-tender—and answered by the tender inside, the valve would be opened and the air allowed to escape, the door at the bottom having been previously closed, and when the air pressure was all off the top door would drop. The lock or shaft is a dark, forbidding-looking place, full of a fog which soon clears out, disclosing an iron ladder down one side and electric lamps for light. After going in, the top door is pulled up by the outside tender, and the pressure pipe opened. As soon as the pressure becomes considerable, the novice becomes "plugged," owing to the pressure on the ear drums pressing them in, but by holding the nose with thumb and finger, and with the mouth closed, a hard blow from the lungs, with distended cheeks, presses them out again, and relief is had. This can also

be overcome by placing the ears close to the outlet pipe and opening the valve. When the pressure in the lock has become equal to that in the working chamber, the lower door drops, and the caisson can be entered. Owing to the excitement and the thought of what might happen, the perspiration comes easy, but the temperature is very little higher than outside. The blow-out pipes extend to the bottom of the end pockets, and when opened the sand and gravel rush to the end of the pipe like tacks to a magnet. Some air escapes with the gravel, the air becomes foggy, and the water

CAISSON NO. 3 BLOWING SAND.

comes in to a depth of six inches, or more; then the blow-out is closed until the air clears, and the water is driven out. The end of the supply pipe is curved and provided with a flap valve, which would close at once in case the supply pipe across the river broke, or the air was shut off in any way.

To sink the caisson the "sand hogs" dig out under the cutting edge, which process is called ditching, then the air is allowed to partially escape, and the caisson sinks or drops down. The chamber becomes foggy and half fills with water, but when the compressed air comes in strong again it clears up and the water is expelled.

The bid in detail upon which this work was awarded is as follows: For pneumatic caisson and crib filled with Portland cement concrete, on a basis of thirty feet or less below low water for pier No. 1, and twenty-four feet for pier No. 2, top of both cribs to be five feet below low water, $8,300; for rock, slate, logs, or bridge iron removed through locks, $9 per cubic yard; for excavation in slate or bed rock requiring blasting, $7 per cubic yard; for extra depth to forty feet below low water, $150 per lineal foot; for extra depth forty to sixty feet below low water, $160 per lineal foot; pier masonry, $7.25 per cubic yard. This was $12.77 per cubic yard of caisson and crib, not including rock, etc., that might be locked out, and $10.16 per cubic yard for extra depth to forty feet below low water. For Pier No. 3 caisson and crib sunk to twenty feet below low water and filled with Louisville cement concrete, $1,600; for all material locked out, $193; for abutment masonry, $6.75 per cubic yard. This is $11,47 per cubic yard of caisson and crib, including all locked out material. Pier No. 1 was sunk 13.15 feet extra depth, and No. 2 18.68 feet extra depth, costing $4,832.80. Twenty-five cubic yards of rock was locked out of No. 1, and eighty-two cubic yards out of No. 2, at a total cost of $988.20, making pier 1 and pier 2 within five feet of low water cost $14,121, or $12.61 per cubic yard. The total amount of masonry in piers No. 1 and No. 2 above the level of five feet below low water, 498.73 cubic yards, and cost $3,615.79, or a total of $17,736.79, or an average for two piers entire of $10.95 per cubic yard. The contractors obtained most of their material and labor at very reasonable prices. For timber $11 per 1,000 feet B. M.; for sand, gravel and bowlders, 25 cents per yard; for stone, $3.35 per cubic yard, delivered at bridge site; for Portland cement, $2.15 per barrel, all delivered at bridge site. Ordinary labor was $1.25 per day; the cost of other labor was from $1.50 to $2.00 per day, except stone-cutters, who received 25 cents per hour; foremen received from $2 to $5 per day.

A. W. JONES.

DRAW-SPAN STRESSES—ASSUMPTIONS MADE TO DETERMINE THEM

THE type of draw-span usually employed is that called the revolving drawbridge, having two equal arms or spans, supported upon a turntable in the center of the total span. The type of truss commonly used now is shown in Fig. 1, and older forms in Figs. 2 and 3. Such forms only will be considered in this article. In order to intelligently discuss the question of making proper assumptions for the determination of stresses, it may be well to assume various conditions and study the effect upon the structure.

Let the bridge be closed and the ends just touching the end supports, but the entire dead load supported by the turntable. If now a uniform live load enters the bridge from one end, the other end will immediately leave its support and continue moving upward until the uniform load covers the first arm, a condition shown roughly in Fig. 4. This result is directly due to the changes in length of the members of the loaded arm, caused by the stresses produced by the live load.

It is evident that the second arm (unloaded arm) will not change its shape owing to the live load in the first arm, since it is simply a cantilever supporting its own weight. Also the pieces marked X are not affected by the live load; hence the conclusion may be drawn that the live load affects only the stresses in the first arm (loaded arm), and consequently this may be treated as a *discontinuous or simple girder resting upon two supports* for the assumed conditions and loading, and the maximum stresses in the truss members found by the usual methods.

The dead load stresses for the condition stated above are evidently those obtained for the case of two cantilever arms balanced upon the turntable, or draw wide open.

The following combinations may be made for maximum stresses:

CASE A. BRIDGE NOT FASTENED AT ENDS WHEN CLOSED.

Chord Stresses. $\left\{\right.$
D.L. (a) Draw wide open.
L. L. (a) Draw closed, *first arm* considered discontinuous or as a simple girder on two supports.

Web Stresses. $\left\{\right.$
D.L. (a) Draw wide open.
L. L. Draw closed, first arm discontinuous.
(a) Partial load extending from A towards Z, Fig. 1.
(b) Partial load extending from Z towards A.

In this day of interlocking switches, signals, etc., the above condition for the live load could only occur through some accident to the interlocking plant, or—in case an interlocking plant is not employed—through gross carelessness on the part of the bridge tender, or unlooked for failure of some member over the turntable or in the substructure.

A condition can be imagined where the arms might be actually discontinuous for both the live and dead loads, as in the case of the sinking of

the pivot pier, but this might not occur during the lifetime of the bridge.

It would seem, therefore, that in designing members for the maximum stresses of Case A, the factor of safety might be considerably less than the factor employed for stresses which may occur every day.

No specifications known to the writer up to the present time have made any differences in the factors of safety for Case A.

The usual condition of the ends of a drawbridge is, that they are locked or fastened after the bridge is closed; sometimes they are *latched down* and sometimes *raised up* a certain fixed amount, but both conditions are not arranged for in the same bridge. These two cases will now be considered.

Suppose the draw closed and the ends of the arms latched down, *but the entire dead load supported by the turntable.* The stresses due to the dead load are evidently the same as for Case A.

If now a uniform live load enters the first arm, the end of the second arm will have a tendency to leave its support, but will be prevented from doing so by the latching apparatus. Therefore there will be a *downward* reaction at this point. All of the other supports will carry some portion of the live load, and hence the bridge for this condition is *continuous* in as much as a load in one span causes stresses in the others.

Supposing for the present that the reactions at all the supports can be found, then for any distribution of the live load it is possible to very nearly select the fields of loading which cause maximum stresses.

Since a live load covering the first arm causes a *downward* reaction at the end of the second arm, the maximum stresses in the second arm due to loads in the first arm will obtain when the uniform live load covers the first arm. For the live load covering the second arm the above would apply to the first arm.

The maximum stresses in the first arm due to the live load in that arm are readily found if the reactions are known.

For maximum stresses when the draw is closed and latched down the following combinations may be made:

CASE B. ENDS LATCHED DOWN.

Chord Stresses.	D.L.	(a)	Draw wide open.
	L.L.		Draw closed and ends latched down.
		(a)	Load in second arm only.
		(b)	Load in first arm only.
Web Stresses.	D.L.	(a)	Draw wide open.
	L.L.		Draw closed and ends latched down.
		(a)	Load in second arm only.
		(b)	Load in first arm only, load extending from A towards Z.
		(c)	Load in first arm only, load extending from Z towards A.

The maximum stresses are readily found by combining the stresses due to the loadings specified above.

A *comparison* of the maximum stresses found for Cases A and B will enable one to *select* the *greatest stresses* in each member of the trusses, and these are the stresses which are to be used in proportioning these members. In case the bridge is designed to be raised by machinery at the ends, after being closed—the general custom now—the stresses due to the live load will be practically the same as in Case B, but those due to the dead load

will be changed, as now some of the dead load will be carried by the supports under the ends of the bridge, instead of all being supported by the turntable as in Case B.

The amount of the dead load carried by the end supports depends upon the amount or distance through which the ends are raised, after the draw is closed and the forces required to lift the ends.

Unless the ends are securely locked in position after being raised it is evident that the upward reaction before any live load enters the bridge should exceed the downward reaction due to one arm fully loaded with the live load, and the other arm unloaded, otherwise the unloaded arm would leave the support as in Case A. Changes of temperature also have bearing upon this point. Having decided upon the amount of uplift the dead load stresses are readily found by the usual methods.

For maximum stresses when the draw is closed and the ends lifted up before any live load enters the bridge, the following combinations may be made:

CASE C. ENDS RAISED.

Chord Stresses.	D.L.	(a)	Draw closed and ends lifted up.
	L.L.		Draw closed and ends lifted up.
		(a)	Load in second arm only.
		(b)	Load in first arm only.
Web Stresses.	D.L.	(a)	Draw closed and ends lifted up.
	L.L.		Draw closed and ends lifted up.
		(a)	Load in second arm only.
		(b)	Load in first arm only, load extending from A towards Z.
		(c)	Load in first arm only, load extending from Z towards A.

The maximum stresses are readily found by combining the stresses due to the loadings specified above.

A *comparison* of the maximum stresses found for Cases A and C will enable one to *select* the *greatest stresses* in each member of the trusses.

Knowing the several cases which must be considered it remains to determine the stresses. The methods for determining the stresses due to the dead load when the draw is open are well understood.

The methods for determining the dead load stresses when the draw is closed and the ends lifted up are not as well known, the difficulty being to determine the proper uplift and the resulting reactions.

Until more work has been done in the way of weighing the reactions of actual structures, probably the best way to determine the uplift reactions is to assume them to exceed by five or ten thousand pounds the downward reaction at the end of the unloaded arm, when the other arm is fully loaded with the live load; the stresses are then readily found.

There are three methods in use at the present time for the determination of the live load stresses. Two of the methods have for their foundation the "three moment theorem," as applied to a *continuous beam of constant moment of inertia*, while the third method depends upon the actual distortion of each piece or member of the trusses under a given loading.

The oldest method (based upon the "three moment theorem") neglects the effect of the unbraced panel over the turntable when designs similar to

Fig. 1 are used, and considers the bridge as a continuous girder of two equal spans upon three supports.

Let

L = the length of the first arm = second arm.
P_1 = any load in the first arm.
P_2 = any load in the second arm.
S_1 = the reaction at A caused by P_1 or P_2.
M_2 = the bending moment at Z caused by P_1 or P_2.
a_1 = the abscissa of P_1.
a_2 = the abscissa of P_2.
x_0 = the abscissa of the point of *zero moment* in the *first arm*.
$a_1 = k_1 L$ and $a_2 = k_2 L$.

Then

For loads in the first arm

$$M_2 = -\frac{k_1 - k_1^3}{4} P_1 L \quad \text{(1)}$$

$$S_1 = +\frac{4 - 5k_1 + k_1^3}{4} P_1 \quad \text{(2)}$$

$$x_0 = \frac{4}{5 - k_1^2} L \quad \text{(3)}$$

For loads in the second arm

$$M_2 = -\frac{2k_2 - 3k_2^2 + k_2^3}{4} P_2 L \quad \text{(4)}$$

$$S_1 = -\frac{2k_2 - 3k_2^2 + k_2^3}{4} P_2 \quad \text{(5)}$$

$$x_0 = 0 \quad \text{(6)}$$

The second method (based upon the "three moment theorem") considers the bridge as *partially continuous* girder of three spans, resting upon *four* supports. Fig. 1. The effect of the unbraced panel over the turntable is considered by assuming the moments at supports *two* and *three* as equal and the shear between them as zero.

Let the length of the center span (the unbraced panel over the turntable) be nL, then

For loads in the first arm

$$M_2 = -\frac{k_1 - k_1^3}{4 + 6n} P_1 L \quad \text{(7)}$$

$$S_1 = \frac{1}{4 + 6n}\left\{4 - 5k_1 + k_1^3 + 6n(1 - k_1)\right\} P_1 \quad \text{(8)}$$

$$x_0 = \frac{4 + 6n}{5 - k_1^2 + 6n} L \quad \text{(9)}$$

For loads in the second arm

$$M_2 = -\frac{2k_2 - 3k_2^2 + k_2^3}{4 + 6n} P_2L \text{ .... } (10)$$

$$S_1 = \frac{M_2}{L} \text{ .... } (11)$$

$$x_0 = O \text{ .... } (12)$$

*The third method (based upon the distortion of each member of the trusses) requires a knowledge of the areas of the members and their lengths. These may be found *approximately* by applying either the first or second methods, then

For loads in the first arm

$$S_1 = \frac{\Sigma_1 \, pul + P_1 (1 - k_1) \Sigma_1 \frac{u^2 l}{a}}{2 \Sigma_1 \frac{u^2 l}{a}} \text{ .... } (13)$$

*This method is fully explained in Part IV Bridges and Roofs, Merriman and Jacoby.

where

Σ_1 = algebraic sum up to the *center of the bridge.*
p = the stress per *unit area* of the member having the length l, caused by the load P_1.
l = the length of the member C — C.
a = the area of the member.
u = the stress in the member caused by *one unit* suspended at the end of the first arm.

$$M_2 = \left\{ S_1 - P (1 - k_1) \right\} L = M_3 \text{ .... } (14)$$

$$x_0 = \frac{k_1}{P_1 - S_1} L \text{ .... } (15)$$

For loads in the second arm

M_2 = moment caused by an equal and symmetrically placed load in the first arm .... (16)

$$S_1 = \frac{M_2}{L} \text{ .... } (17)$$

$$x_0 + O \text{ .... } (18)$$

The stresses due to P, and the *unit load* at the end of the arm are determined for the condition where the first arm is *cantilevered* from the turntable.

Having found the reactions by one of the above methods, the stresses in the individual members of the trusses are readily found by well known processes.

From a theoretical point of view, the first two methods are defective

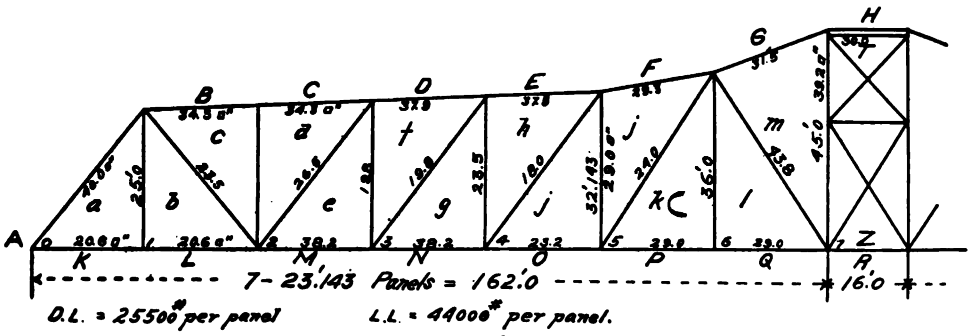


FIG. 1.

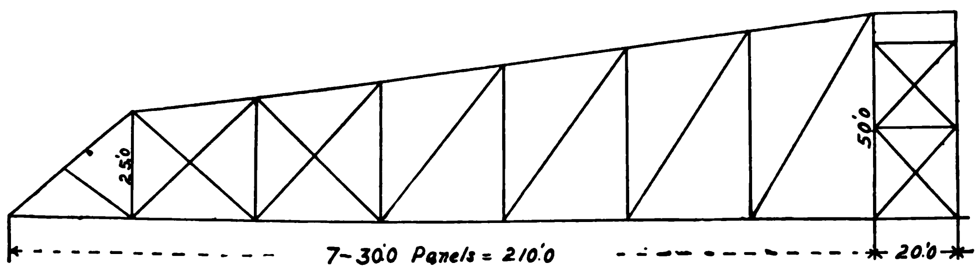


FIG. 2.

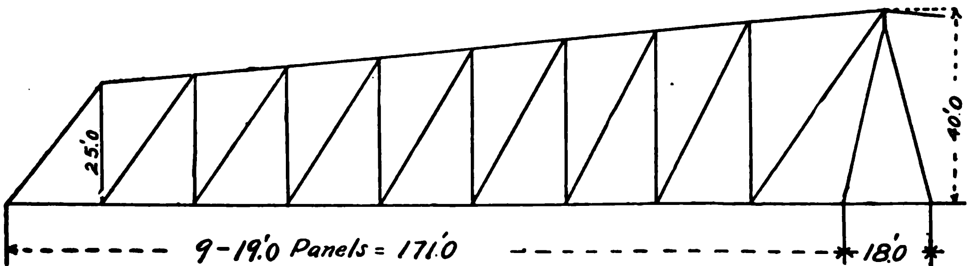


Fig. 3.

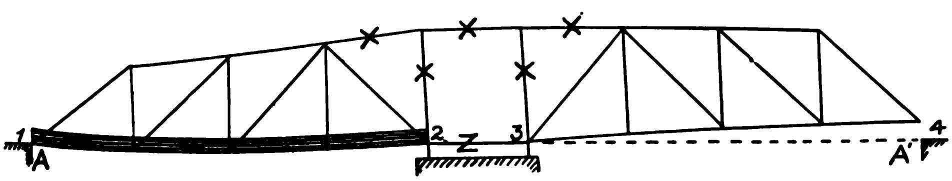


FIG. 4.

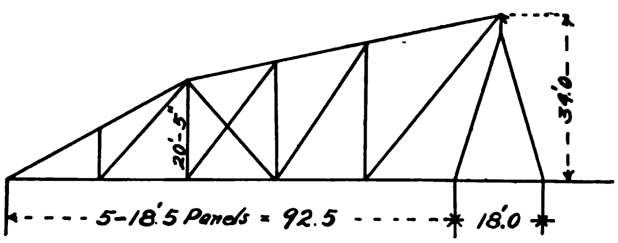


FIG. 5.

in that a theory deduced for a solid beam of constant cross-section is applied to trusses of variable depths and variable moments of inertia.

The third method is defective since it is based upon the assumption that the trusses are perfect articulated frames, in which the members are distorted longitudinally *without bending*.

Since the usual type of truss employed has several panels in the top and bottom chords which are made continuous, and the stringers supporting the track are riveted between the floor beams (which are riveted to the verticals of the trusses), and thereby acting to a considerable extent with the bottom chords of trusses, it is evident that the actual state of affairs is not covered by any one of the above three methods.

The third method appears to be the most consistent, and probably leads to fairly close results—quite close enough for all practical purposes.

One great objection to the method is that a trial set of computations must be made to determine the approximate areas of the truss members, and then, too, the numerical work in computing the values of S_1 is rather tedious even with the aid of the slide rule.

For the usual type of truss (Fig. 1) the *final stresses*, after all combinations have been made, do not differ greatly in magnitude, so that the particular method employed in determining the live load stresses is of little importance. From this point of view the first method would appear to be sufficiently accurate for all practical purposes.

In order to show the discrepancies between the stresses determined by the three methods, a typical bridge has been selected, and the stresses determined and tabulated below. (See Fig. 1):

TABLE I.

Comparison of the values of S_1 for loads in the first arm as found by different methods. (See Fig. 1.)

LOAD 44,000 AT PANEL.	Method No. 1. (1)	Method No. 2. (2)	Method No. 3. (3)	$\frac{(3)}{(1)}$ (4)	$\frac{(3)}{(2)}$ (5)
1	36,200	36,400	36,400	1.006	1.000
2	28,600	28,900	28,800	1.007	0.996
3	21,300	21,800	21,600	1.014	0.991
4	14,600	15,200	14,700	1.007	0.967
5	8,700	9,200	8,400	0.965	0.913
6	3,800	4,100	3,600	0.974	0.878
Over all	113,200	115,600	113,500	1.003	0.982

From Table I it appears that the value of S_1 for the first arm loaded at each panel point, is very nearly the same for all methods. The maximum discrepancy obtains for a single load at 6 where the ratios are 0.947 for the common method and 0.872 for the second method. It also appears that the first method leads to results which agree more nearly with those obtained by the third method, than the second method.

According to results obtained by Professor Turneaure, the second method gives more accurate results than the first method. This is probably due to the fact that he considered trusses of a different type.

Quoting from Professor Turneaure's paper, published in the *Engineering News*, December 3, 1896. . . . In every case a load of unity per lineal foot extending over the entire bridge has been assumed. The following bridges have been treated:

(a) The Winona Bridge, a description of which will be found in *Engineering News*, Vol. XXVI., 1891, p. 370. A sketch of this bridge is given in Fig. 2.

(b) A series of designs, with the half-truss containing 6, 5, 4, 3, and 2 panels successively. The general dimensions of these trusses were chosen by taking a corresponding number of panels of the Winona Bridge. Cross-sections of numbers were properly determined from stresses due to certain assumed dead and live loads. . . . . .

(c) Another bridge of a form similar to the Winona Bridge, but with five 18-ft. panels, a central panel of 18 ft., a center height of 32 ft., and end height of 25 ft.

(d) The Milwaukee drawbridge of the C., M. & St. P. Ry., which is described in the *Engineering and Building Record*, Vol. XVI., 1887, p. 784. Fig. 5 is a sketch of this bridge.

(e) The Sabula swing bridge as shown in Fig. 3 . . . . . . The cross-sections of the web members not being at hand, the required sections have been obtained by computation. . . . . . .

Professor Turneaure's results are given in Table II:

TABLE II.

Values of S_1 for a load of unity per lineal foot over the *entire bridge*, as found by different methods.

BRIDGE.	No. of Panels.	Method No. 1. (1)	Method No. 2. (2)	Method No. 3. (3)	$\frac{(3)}{(1)}$ (4)	$\frac{(3)}{(2)}$ (5)
a	7	64.3	67.4	65.9	1.025	0.963
b	6	53.1	56.3	57.7	1.087	1.025
b	5	42.0	44.7	47.0	1.119	1.051
b	4	30.9	33.1	36.1	1.168	1.091
b	3	20.0	22.1	25.2	1.260	1.140
b	2	9.4	11.0	11.9	1.266	1.082
c	5	34.2	36.7	38.2	1.117	1.041
d	5	47.5		44.5	0.937	....
e	8	58.1		56.6	0.974	...

Columns (4) and (5) show conclusively that the second method is more accurate than the first case for the cases considered, and also, that for trusses with less than six panels, both methods are considerably in error, all comparisons being made with the results from the third method.

From Tables I and II it follows that for trusses with at least seven panels in each arm, either method number one or number two is quite accurate enough as far as the values of S alone are concerned. It does not necessarily follow, however, that the maximum live load stresses will be in as close agreement when computed by the three methods. This is clearly shown in the Tables III and IV, which give the relative values of the results found by the *third method* with those found by the other two methods.

TABLE III.

Relative values of web stresses due to a uniform live load. Fig. 1.

PIECE.	Method 3 / Method 1		Method 3 / Method 2		REMARKS.
	Comp.	Tension.	Comp.	Tension.	
Aa	1.003	0.983	0.982	1.121	The stresses upon which these ratios are based were computed to the nearest hundred pounds before any combinations were made.
bc	0.982	1.001	1.077	0.974	
de	0.998	0.982	0.951	1.048	
fg	0.983	0.985	0.937	1.034	
hi	0.955	0.989	0.909	1.028	
jk	0.944	0.999	0.850	1.016	
lm	0.997	----	1.070	----	
cf	0.986	0.998	1.042	0.960	
gh	0.983	0.983	1.035	0.935	
ij	0.994	0.961	1.015	0.814	
mT	0.981	----	1.143	----	

TABLE IV.

Relative values of chord stresses due to a uniform live load. Fig. 1.

PIECE.	Method 3 / Method 1		Method 3 / Method 2		REMARKS.
	Comp.	Tension.	Comp.	Tension.	
Ka, Lb	0.981	1.000	1.125	0.979	The stresses upon which these ratios are based were computed to the nearest hundred pounds before any combinations were made.
Me	0.982	1.004	1.127	0.971	
Ng	0.982	1.008	1.127	0.958	
Oi	0.981	1.014	1.125	0.927	
Pk, Ql	1.013	1.265	1.127	0.696	
Bc, Cd	1.004	0.980	0.978	1.126	
Df	1.005	0.981	0.971	1.127	
Eh	1.008	0.982	0.957	1.127	
Fj	1.014	0.981	0.925	1.125	
Gm	----	0.982	----	1.127	
HT	----	0.926	....	1.126	

From Table III it is seen that members Aa, jk, and mT show the greatest disagreement in their stresses, as found by the three methods. When the dead load stresses are combined with those due to the live load these differences will be considerably changed, as shown later on.

From Table IV it is seen that the chords Pk and Ql have very different tension stresses according to the three methods, while the remaining chords show fairly close agreement between methods *one* and *three*.

Although the above Tables III and IV indicate that, for satisfactory live load stresses under the assumptions of continuity, method number *three* should be employed; yet these stresses may not be the governing factors in the final maximum stresses required for designing the different members.

TABLE V.

Maximum stresses due to live and dead loads when the draw-bridge is designed to be *latched down* and not lifted at the ends (the entire dead load being supported by the turntable at all times). Fig. 1.

PIECE.	METHOD. 1	2	3	METHOD. 1	2	3
	Positive Stresses.			Negative Stresses.		
Aa	163.9	do	do	32.2	29.2	31.8
bc	56.8	54.4	57.4	89.8	89.8	89.8
de	34.7	do	do	94.2	90.8	93.3
fg	o	do	do	137.0	133.1	135.8
hi	o	do	do	185.4	180.9	184.5
jk	o	do	do	218.2	215.6	218.1
lm	184.8	182.0	184.4	o	o	o
ef	76.0	73.7	75.4	22.8	do	do
gh	110.2	106.9	109.1	o	do	do
ij	132.8	130.9	132.3	o	do	do
mT	118.6	111.1	117.6	o	do	do
KaLb	20.5	18.5	20.2	104.0	do	do
Me	87.0	81.4	86.2	159.0	do	do
Ng	131.1	124.0	130.1	120.8	do	do
Oi	181.7	173.0	180.4	44.3	do	do
PkQl	221.3	213.8	222.3	o	do	do
BcCd	155.4	do	do	49.0	46.0	49.3
Df	159.2	do	do	87.2	81.5	86.4
Eh	120.9	do	do	131.3	124.1	130.3
Fj	45.0	do	do	184.3	175.4	183.0
Gm	o	do	do	317.4	298.7	314.8
HT	o	do	do	295.8	278.3	293.2

TABLE VI.

Maximum Stresses due to live and dead loads when the draw-bridge is designed to be *lifted up* at the ends and not latched down. Fig. 1.

PIECE.	METHOD. 1	2	3	METHOD. 1	2	3
	Positive Stresses.			Negative Stresses.		
Aa	163.9	163.9	163.9	12.9	9.9	12.5
bc	39.3	36.3	38.7	89.8	89.8	89.8
de	35.5	37.7	35.4	76.5	73.1	75.6
fg	o	o	o	120.2	116.3	119.0
hi	o	o	o	169.3	164.8	168.0
jk	o	o	o	210.9	208.8	210.8
lm	191.6	182.0	191.2	o	o	o
ef	62.4	60.1	61.8	23.4	25.1	23.3
gh	97.1	93.8	96.0	o	do	do
ij	126.6	124.7	126.1	o	do	do
mT	98.0	90.5	97.0	o	do	do
KaLb	8.2	6.2	7.9	104.0	do	do
Me	52.3	46.7	51.5	159.0	do	do
Ng	86.5	79.3	85.5	120.8	do	do
Oi	127.7	119.0	126.4	44.3	do	do
Pk Ql	163.4	155.9	164.4	o	do	do
Bc Cd	155.4	do	do	34.1	30.2	33.5
Df	159.2	do	do	52.5	46.8	51.7
Eh	120.9	do	do	86.6	79.4	85.6
Fj	45.0	do	do	129.6	120.7	128.3
Gm	o	do	do	259.3	240.6	256.7
HT	o	do	do	241.8	224.3	239.2

The final maximum stresses for the bridge shown in Fig. 1 have been tabulated in Tables V and VI, from which it is evident that for this bridge method *number one* is quite accurate enough for all practical purposes, and that method *number two* does not lead to dangerous errors, since the greatest discrepancy between all methods is less than 10 per centum for any member which has a stress of any considerable magnitude.

In conclusion, then, it may be safely stated:

1. For short spans or where great accuracy is required, method *number three* should be used for determining the live load stresses.

2. For long spans, that is trusses with at least seven panels in each arm, method *number one* is quite accurate enough for bridges of the type shown in Fig. 1.

3. For long spans method *number two* may be employed for bridges of the type shown in Figs. 2 and 3.

MALVERD A. HOWE.

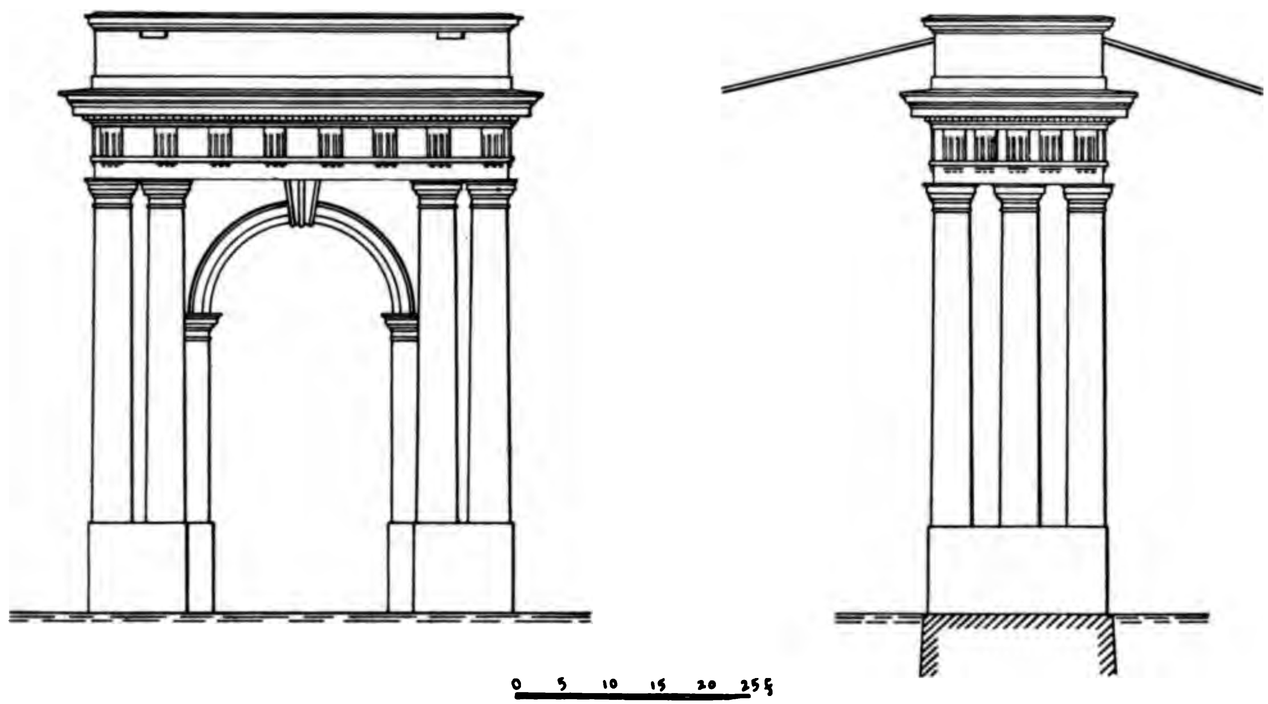
THE ARCHITECTURE OF BRIDGES

THERE is no system of architecture for bridges analogous to that for buildings, nor does there seem to be any possible scheme of classification with reference either to the artistic features of bridge construction, or with reference to the eras during which they were built, having at the same time regard to the style or form. Details can be found in almost any design for a bridge, especially for an arch or a suspension bridge, which would suggest some architectural style, but considering the structure as a whole, it would be difficult, with strict regard to the proprieties, to include it in any particular group. The suspension bridge at Fribourg may be taken as an example of this—the towers are beautiful pieces of Roman Doric architecture. The columns or pilasters have no bases, but rest directly upon plain rectangular pedestals, the entablature is well designed, being detailed quite accurately, and properly ornamented with triglyphs, while above the cornice is an attic story, which marks each tower as complete—this being the feature lacking in the design of many other notable suspension bridges. The span between the towers, although pleasing, has no feature which is architectural, and the bridge as an entirety cannot be classed as Doric.

The suspension bridge at Budapesth has towers which are good pieces of architecture, the frieze being highly ornamented, and the cornice surmounted by an attic story; the toll houses are of simple classic design, and the entire bridge an extremely harmonious structure—perhaps the most so of any one of the kind extant—yet it is not a work of architecture that can be classified. There are many others with towers of elegant design and pleasing proportions, with details which are quite proper, but which do not conform to any style.

Stone arch bridges are but little more promising with regard to possible architectural classification. The old Roman bridge of St. Chamas, built by Augustus, or during his time, over the Tolubre, has at each end beautiful triumphal arches over the roadway. They are of Corinthian design, very rich in detail, and the architecture is said by Cresy to be the best of this age to be found in Gaul. The arch of the bridge is of such ordinary design as to cause no comment by itself. Another and more pretentious bridge, made notable by reason of arches over the roadway, near the center of the stream, is that at Saintes over the Charente. Here there are two arches side by side, the details being Corinthian, but the proportions are not good. This part of the bridge was built of materials brought from Mediolanum in 1812, and it is believed that the proportions were different and probably correct in the original structure.

The old Roman bridge built by Augustus at Rimini was decorated over the piers with two columns carrying a pediment and occuping the location of counterforts. A similar device was adopted on many subsequent ones, among which are several prominent English stone bridges. The Blackfriar's bridge having two Ionic columns over each pier, supporting an architrave underneath the cornice. The Waterloo bridge over the Thames and the



TOWER OF FRIBOURG SUSPENSION BRIDGE. (DETAILS MERELY INDICATED).

Hutcheson bridge over the Clyde at Glasgow have two Grecian Doric columns over each pier, supporting an architrave and frieze under the cornice. Such ornamentation is in very bad taste, and entirely foreign to bridge design.

The arches themselves should furnish the means of architectural classification, but there are few forms peculiar to any style, most bridges having either circular or elliptical curves for the intrados. Those having pointed arches, might on this account be classed as Gothic. Examples of this would be the ancient bridge over the Ouse at York, England, which was built during the reign of Elizabeth. This had one large pointed arch, flanked by two

TOWER AT BUDA-PESTH.

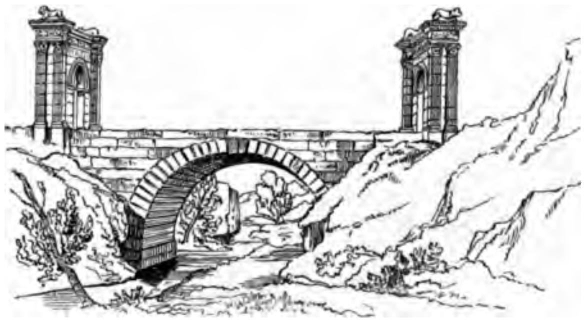
smaller pointed arches in each approach, supporting on one side a Gothic chapel.

The bridge of the Trinity at Florence, Italy, has three large arches, with a slight angle at the top, but the curve of the intrados is nearly an ellipse.

Persian bridges were many of them constructed with pointed arches—that one known as Allah Verdi Khan, one at Shuster, over the river Karun, and another at Dizful, over the river Diz: this latter having twenty arched openings and piers equal to or exceeding the openings, the piers being pierced with pointed arches above the level of the springing of the main spans.

The old Roman bridges were built with circular arches, and their architectural effect is due mainly to their simplicity of design. Fergusson says of them: "The Romans set about works of this class with a purpose-like earnestness that always insures success, and executed them on a scale which leaves nothing to be desired; while at the same time they entirely avoided

that vulgarity which their want of refinement allowed almost inevitably to appear in more delicate or more ornate buildings. Their engineering works were also free from that degree of incompleteness which is inseparable from the state of transition in which their architecture was during the whole period of the Empire. It is owing to these causes that the substructions of the

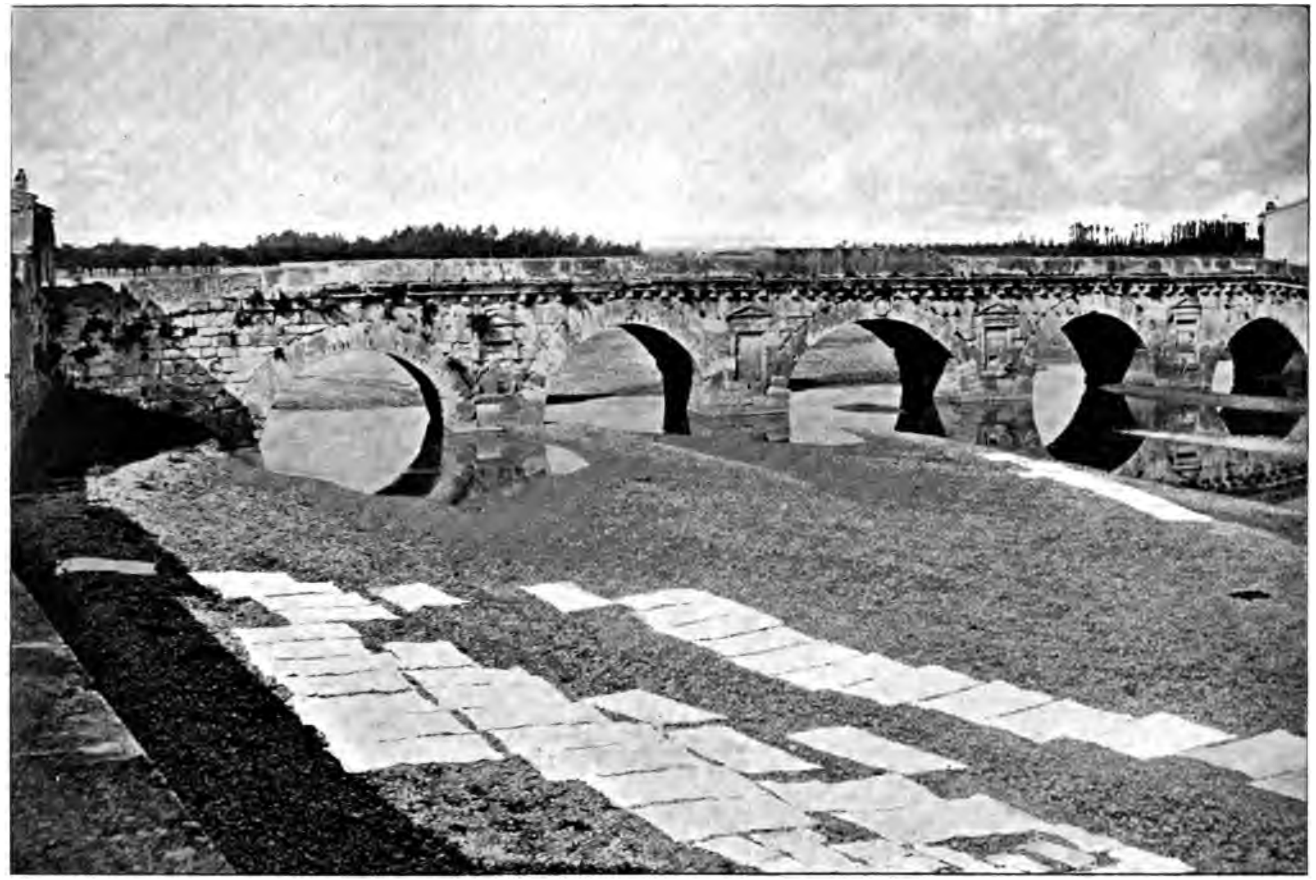


BRIDGE OF ST. CHAMAS.

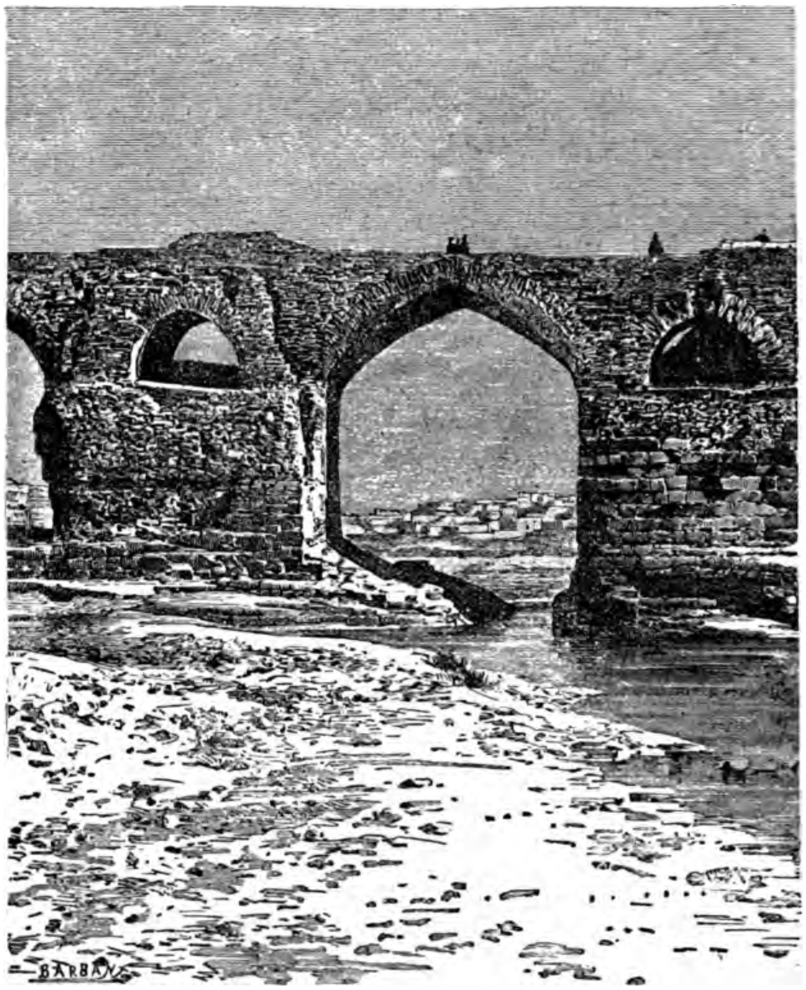
Appian Way strike every beholder with admiration and astonishment; and nothing impresses the traveler more, on visiting the once imperial city, than the long lines of aqueducts that are seen everywhere stretching across the now deserted plain of the Campagna. It is true they are mere lines of brick arches, devoid of ornament and *of every attempt at architecture properly so called;* but they are so well adapted to the purpose for which they were designed, so grand in conception, and so perfect in execution, that, in spite

BRIDGE OF ST. CHAMAS.

of their want of architectural character, they are among the most beautiful of the remains of Roman buildings. The aqueducts were not, however, all so devoid of architectural design as those of the Campagna. That, for instance, known as the Pont du Gard, built to convey water to the tower of Nimes, in France, is one of the most striking works of antiquity. Its height above the stream is about 180 feet, divided into two tiers of larger arches surmounted by a range of smaller ones, giving the structure the same finish and effect that an entablature and cornice give to a long range of columns.



AUGUSTUS BRIDGE AT RIMINI.



PERSIAN BRIDGE AT DIZFUL.

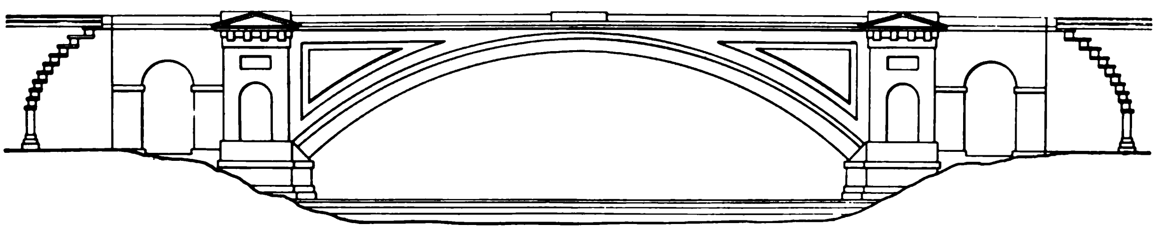
Without the introduction of one single ornament, or of any member that was not absolutely wanted, this arrangement converts what is a mere utilitarian work, into an architectural screen of a beauty hitherto unrivaled in its class.

"The aqueducts of Segovia and Tarragona, in Spain, though not perhaps so grand, are quite as elegant and appropriate as this; and if they stood across a line of well wooded and watered valleys, might form as beautiful objects. . . . . .

"The Roman bridges were designed on the same grand scale as their aqueducts, though from their nature they, of course, *could not possess the same grace and lightness.* This was, however, more than compensated by their inherent solidity, and by the manifestation of strength imparted by the Romans to all these structures. They seem to have been designed to last forever; and but for the violence of man, it would be hardly possible to set

limits to their durability. Many still remain in almost every corner of the Roman Empire; and wherever found are easily recognized by the unmistakable impress of *Roman grandeur* which is stamped upon them."

The adoption of flat arches occurred about the end of the Seventeenth Century, and rendered possible the construction of more beautiful arches. The French engineers were satisfied to construct their bridges from simple designs, applying the principles of architecture to the working out of the details, which were usually quite appropriate. English engineers, on the other hand, made the very frequent mistake of adding architectural features which were inappropriate. The most remarkable example of this is the bridge over the Dee at Chester, England. The span is 200 feet—making it the third largest stone arch in existence—the rise 42 feet and the depth of keystone 4 feet 6 inches. These dimensions should make the bridge one of the most striking, and had the engineer been of the same mind as the designer of the Cabin John bridge at Washington, adopting simplicity instead of inappropriate decoration, its grandeur would have been unquestioned. The arch ring is decorated with a common architrave molding, the



CHESTER DEE BRIDGE.

spandrels have panels 30 by 50 feet, niches are provided on the abutments, pediments added, and small approach arches used—all contributing to dwarf the span, so that it seems of only a medium size.

Framed structures of timber and metal fortunately offered less chance for the addition of architectural ornament, and as a consequence they more nearly conform to good engineering, which has been defined as "the art of disposing the most suitable materials in the most economical but scientific manner to attain a given utilitarian end."

There are, however, conspicuous examples of failure to keep within the bounds of reason here, a well known example being the straight truss bridge at Philadelphia, where each panel is converted into a false arch, forming an arcade in mid-air—a most ridiculous design. Few truss bridges are deserving of record as having any truly architectural features, unless it be those with masonry portals, which are in many instances decidedly inappropriate.

The portals of the bridge at Kamfer, Holland, are well designed, and as fitting as such heavy appendages to a lattice girder bridge could be. They are finely detailed, of mediæval design, with battlemented parapets, and would doubtless be used for defense in time of war. Four towers, of the same design as those in the portals, flank the insignificant draw or lift span, and are very much out of place. If the bridge was of extremely heavy construction and the lift span a large and important one, like the Tower Bridge at London, the portals and towers would have been more harmonious

PORTAL OF KAMFER BRIDGE.

and pleasing features, but they do not stamp the bridge as a work of architecture.

The most conspicuous and most noticeable instances of the use of heavy portals for truss bridges, are at Hamburg, Germany, where the two Pauli trussed structures, owing to their proximity, are so readily compared. The old bridge, with its simply designed portal, rectangular in plan, plain and severe in detail, is much more harmonious than the new bridge with portals of ornate design, heavy in appearance, and lacking any features of harmony with the bridge itself.

Arch bridges of metal are always and of necessity more or less æsthetic in design, and are very frequently harmonious compositions. The arch bridge over the Rhine at Mayence is an exquisite conception, rich in detail, harmonious in design, and while violating some of the fundamental ideas of architecture, it is a notable piece of work.

The Washington bridge over the Harlem River is another fortunate design with regard to harmony, although it would have been more pleasing had there been three instead of only two large spans, thus conforming to the first principle of bridge design, which requires an opening and not a pier at the center of a composition. The approaches were much improved over the original design, which had nearly solid walls of masonry flanking the metal spans, by the adoption of stone arched approaches, which were lighter and more harmonious.

The Eads bridge, over the Mississippi at St. Louis, has three noble arches over the river, and is flanked by arched approaches, which have a first story of large stone arches, supporting a second story of small arches, which also serve the purpose of admitting light to the railways at this level.

As a means of architectural classification, these, however, offer nothing sufficient to characterize them as belonging to any style.

The greatest bridges built during recent years have many of them been cantilevers, and they have been designed in the majority of cases with regard only to utility and economy and are not often pleasing in appearance nor always of symmetrical outline. The great Forth Bridge is undeniably grand and imposing, the design is symmetrical, the curved outline of the bottom chords graceful, but with the broken outline of the top chords the ensemble is not pleasing, and it has been said by an engineer who visited it, to resemble nothing so much as three huge elephants wading in the Forth. It is doubtful, however, if it could have been much improved in æsthetics, without the use of a radically different design or perhaps a different type of bridge altogether.

The Niagara cantilever, the Poughkeepsie cantilever, and others of similar outline, could have been rendered pleasing in appearance by using an arched outline for the bottom chords, without great loss in economy or much sacrifice in stiffness.

The Memphis bridge being a through cantilever, was a much more difficult problem, and it is doubtful if much improvement in outline could have been made, except by some modification which would have rendered the main structure symmetrical.

There is another class of structures—draw spans—which do not seem susceptible of modification in any way which will render them works of art. With the long spans demanded by modern commerce, a high tower is neces-

KAMFER BRIDGE, GENERAL VIEW.

sary over the pivot pier for economy, and there is consequently a striking resemblance to the outline of the Forth Bridge. Attempts to render them more pleasing by the curving of the top chords are most successful when the top chord is curved between the tower and the hip. For when reverse curves are used over the tower and the extreme ends, a clumsy effect is produced.

This somewhat hasty review of forms of bridge construction and the embellishment of bridge structures makes it evident that no systematic scheme of construction has been employed, analogous to architecture, and that the details used to ornament bridges do not serve to mark a style, being often inappropriate as well.

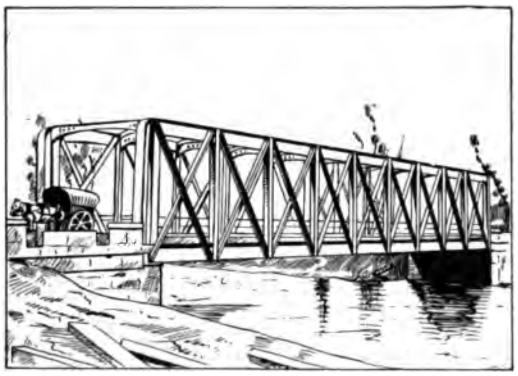
There remains then to state clearly the underlying principles of artistic bridge design—of symmetry, proportion, and harmony—as a nucleus for a comprehensive system of *Bridge* Architecture. This will be attempted in future articles.

MODERN SPANISH BRIDGE ENGINEERING

THE writer spent nearly twelve months in España, visiting the state three times. It is a surprise to find, especially in the northeastern parts of the Iberian peninsula, fine and handsome iron bridges springing up everywhere, built entirely with Spanish materials and by Spanish hands. It is largely due to the native bridge engineers organized at Barcelona (Sociedad de Ingenieros Industriales) that these results have been accomplished.

The San-Andrés-cross bridge over the river Henares is a bridge which was constructed in 1889. It is solely of one span, forty-two meters forty centimeters in length. The total width is six meters. The roadbed has four and one-half meters, and the combined width of the two footways is one and one-half meters.

The principal iron beams are a lattice-work in the form of a Saint Andrews cross, and there are vertical iron stay-posts. These supports have a height of six and one-tenth meters, and are braced together above. The roadbed



BRIDGE OF CRUS-DE-SAN-ANDRES, OVER THE RIVER HENARES,
ON THE HIGHWAY FROM AJALVIR TO ESTREMERA.

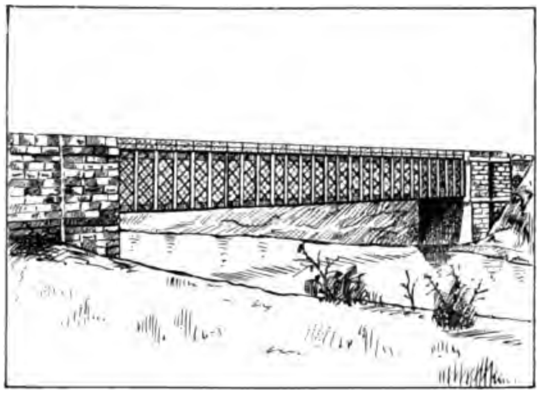
is inferior (through bridge). The cart track is macadamized, sustained by *zorés* irons. The ground-work of the sidewalks is of iron plating, grooved. This is, for España, a very pretty modern bridge.

The writer has tramped afoot over two hundred miles of Spanish country roads, but never saw a better looking *puente* than that over the Henares, during a long ramble afoot in the spring of 1891. Some of the rural bridges looked quite six hundred years old, and were so worn out—though still used—that even the keystone ridges were half worn through. It was enough to make one hoary looking at them.

The multiple-mail bridge over the river Tajo was constructed in 1880. It is of one sole span, of fifty-two meters longitude. It has a total width of six meters forty centimeters; four meters forty centimeters of roadbed, and one meter each side path. The principal beams are a lattice of multiple mail-work, and have an altitude of four meters eighty centimeters. The

roadbed is here the superior part of the bridge (deck bridge). A forged-iron balustrade protects the walks. The ground-work, both for the road and the paths, is of wood.

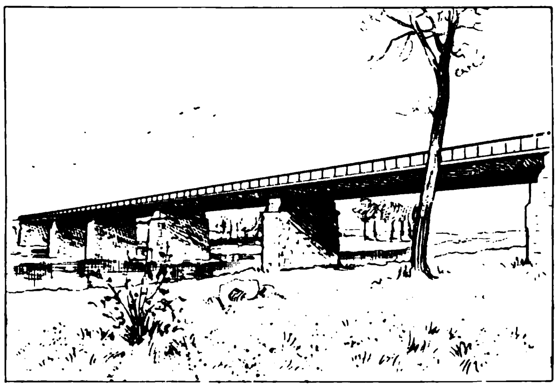
This is a specially good example of Iberian bridge engineering. It was built, as were all the others, by the *Sociedad Material para Ferrocarriles and Construcciones*, Ancha 2, Barcelona. This is the great railroad supply



MULTIPLE LATTICE BRIDGE OVER THE RIVER TAJO, ON THE HIGHWAY FROM TARANCON TO ARMUNA.

trust of the peninsula. The aged M'l Girona is technical director, and he is Barcelona's architectural benefactor. It was Girona who, out of his own pocket (1,000,000 pesetas—$200,000), restored to a type of beauty, the city's hoary cathedral pile, converting it into another Milano, on a small scale.

The Alma-Llena bridge, over the river Francoli, was constructed in 1879.



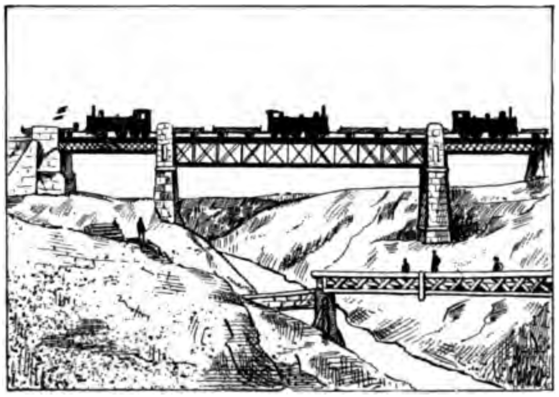
BRIDGE OF ALMA-LLENA, OVER THE RIVER FRANCOLI, ON THE HIGHWAY FROM ALCOLEA-DEL-PINAR TO TARAGONA.

It has five solitary spans, of twenty-seven meters each. It is ten meters sixty centimeters wide—that is to say, six meters twenty centimeters for the roadway, and two sidewalks of two meters twenty centimeters. The principal beams or supports are of solid columns, four meters twenty centimeters in height. The walks are "winged" (projecting beyond the supports), and have a balustrade of forged iron—which design is distinguished in the

illustration. The roadbed—both of the cart-track and two footpaths—is of macadam, sustained by buckled plates.

The parabolic bridge over the river-bed of Vilamajor was constructed in 1883. Length, twenty-nine meters—one span; width, five meters, being three meters seventy centimeters for the road, and sixty-five centimeters for each sidewalk. The principal supporting beams (trusses) are parabolic, and the cross-pieces take the form of N. They are three meters thirty centimeters in height at the center. The roadway, which is on the lower part of the bridge, is a compact stone road, sustained by small vaulted brickwork supported on the transverse beams. The floor of the sidewalk is of wood.

The waterway, like many others in España, is completely dry during a good part of the year; but at times there are strong and copious floods, in



BRIDGE OF CRUZ-DE-SAN-ANDRES OVER THE RIVER VINAALPO, ON THE ECONOMIC RAILROAD FROM VILLENA TO ALCOY.

which case it is of necessity to have a strong bridge over the waterway.

Of the cross-bridge of San-Andrés over the Tio Vinalapó, the date of construction was 1884. It is of three independent spans: one, central, of thirty meters length, and two laterals of twelve and one-quarter meters each one. This bridge is for a narrow-gauge railroad (one meter between rails). It has two meters' width between the centers of the principal beams, and moreover a little "winged" walk, of fifty centimeters' width, to each side. The leading stays are of iron, having the form of a cross of St. Andrew, and with vertical joists. Those of the central span are three meters high, and those of the lateral spans are one and one-half meters. The track is superior (deck bridge). The rails are laid on iron jamb-posts, fixed to the transverse beams. The narrow foot-ledges have a wood flooring.

In the photograph taken of this bridge may be seen various locomotives and wagons occupying completely the three spans. This represents the act of verifying one of the proofs to which this bridge was submitted.

All of these bridges are of laminated iron, and are constructed according to the European system of rigid joinery, obtained by means of sufficient riveting. In all these bridges there is no forged work, so that the bars of

iron, once out of the hands of the laminator, solely necessitate the labor of cutting, perforating, and riveting.

The three bridges previously mentioned are calculated for resisting, in addition to the permanent load, two classès of moving loads, as is prescribed in the regulations of bridges for the cart tracks of España. One of the proof-loads is the *estatica* (science of weighing bodies), the estimation being 300 kilos—660 pounds per square meter. The other test is known as the *rodada*, or rolling proof, produced by carts, which fill the bridge, each one of a weight of nine tons when of two wheels, and of twelve tons when they are tilt carts of four wheels. In the bridge over the river Henares, the framings, because they are of great length, are formed by bars composed of two angle irons, and a sole of plane iron some in form of a ⊥, while others are in the form of ⊔, with the object of obtaining sufficient rigidity, or transverse resistance.—*W'r Lodia, in Mun. Eng.*

PARABOLIC BRIDGE OVER THE RIVER-BED VILAMAJOR, ON THE HIGHWAY FROM LLINAS TO SAN-CELONI.

THE BRIDGE WORK'S ESTIMATING DEPARTMENT

SYSTEM is important in any branch of an engineer's work, but nowhere more important than in estimating bridges and structural work. Its importance in the estimating department of a bridge works is increased about in proportion to the variety of the work handled. Small losses of time, which would be inconsiderable in a railroad office dealing with a single specification and only two or three classes of loading, would become a serious matter in the office of a bridge company, which has to deal with all specifications and with all classes of material, often with the most diverse in the course of a single day.

A consulting engineer, and to a certain extent a railroad engineer, may set the time for receiving bids to suit the work in hand, but a bridge company must be prepared to submit a proposal by a certain time or not at all. Every device for shortening the labor of estimating, while avoiding guess work, is acceptable.

A bridge company has to deal with such a variety of specifications that it becomes impossible for an estimator to carry in mind the provisions of them all. To overcome this difficulty the writer has long made a practice, following the suggestion of Mr. Edwin Thacher, member American Society Civil Engineering, of making an abstract of a new specification on the first occasion for using it, and saving this abstract to be used in place of the specification in the future. This was found to effect such a saving in time and so materially to reduce the liability to error, that the writer finally prepared a printed form for the purpose, which reduces the labor of making an abstract to a minimum. Such an abstract will condense into two sheets 8½x14 all that an estimator needs to know in order to avoid errors in designing according to a given specification. The first sheet gives all data as to loads and unit stresses, and all those items to which constant reference has to be made, while the second sheet gives all the other items that need to be looked over in order to refresh the memory on beginning an estimate. There is an entire absence of all those items which are common to all specifications. The forms are filled out to assist in estimating rather than in detailing, although a similar abstract from the standpoint of the detailer would doubtless save time.

Next to a knowledge of the specification to be used, a careful outline of the work to be done is important. Time spent in making a diagram of the structure and in considering the work in all its bearings is generally well spent, and will be more than made up before the estimate is complete. Blanks for estimates should provide a liberal space for a line diagram, which should as far as possible clearly indicate every member, and should be lettered so that each member may be referred to without excessive writing in the body of the estimate. Such a sketch will take some time to make, but it enables an estimator to get the structure well in hand, saves time and mistakes in setting down, and greatly reduces the labor of checking and making strain sheet. An estimate without a clear sketch is about the most unsatisfactory affair that can be imagined.

Having determined the outline and general character of the work, the next important step is to determine the stresses in the structure. For this purpose it is impossible to say of any one method that it is best for all cases. The method of determining the stresses must depend on the character of the structure, and to a certain extent on the training of the engineer. For railroad work the use of wheel loads is happily not so common as formerly. It involves great labor for simple trusses, and excessive labor for odd trusses, while for draws and complicated trusses the time involved makes its cost prohibitory. The equivalent load method, which is largely used in place of wheel loads for purposes of calculation, has such decided advantages as to cost that it is likely soon to become universal.

For truss work the writer prefers the equivalent load based on the shear in the endpost to that based on center moment. The equivalent load from

THE COMPTOMETER.

end shear gives excess of metal in counters where it is well placed, and also in the chords. The equivalent from center moment gives more nearly the true stresses in the chords, but gives a deficiency in other members, which is not to be commended. Recent extensometer tests would seem to indicate that the specifications of the future would give more weight to chord stresses than has been customary.

Those systems of equivalent loads which use a compromise between the two above mentioned are more complicated and cannot be said to give as good a bridge as the equivalent based on the end shear, while the saving in weight is not often enough to justify much extra expense in estimating. Equivalent loads based on center moments are without objection for girders of ordinary span and for floor beams and stringers. The use of a uniform load with the addition of a single or double concentrated load, is somewhat more cumbersome than the method of equivalent loads above mentioned, but still effects a decided saving of time over the use of wheel loads.

After the panel loads are determined the stresses in the various members may be obtained graphically by diagraming back from the end reaction; or, in the case of uniform loads, by complete diagraming for each separate panel load, and then combining for maximum stresses; or in any

case by the method of moments. The writer prefers the method of moments for all ordinary structures, as he finds that it is more accurate, while it permits the labor of calculation to be reduced to a minimum by the use of the slide rule. If the points of chord intersection are calculated and the diagram drawn to reasonable scale, the arms of the various forces may be measured with sufficient accuracy. All distances are easily reduced to panel lengths by the use of a slide rule, and it will be found that the calculations are much simpler when this is done. A smaller diagram using a panel length for the unit will then afford a reasonable check upon the accuracy of the arms first obtained.

For three hinge arches with spandrel bracing, and for odd trusses, where the conditions for maximum stress are not apparent, the graphical method using apex loads is generally most satisfactory. For arches with constant depth and constant cross-section the writer considers the method given in Professor DuBois' last edition of "Framed Structures" to be best; while for Melan arches and steel arched ribs, with varying cross-section, he prefers Professor Cains' graphical method. Professor Howe's analytical method

THATHER'S SLIDE RULES.

may be used with satisfaction for many cases of arched ribs, while it offers a thorough method of obtaining the deflections in such ribs. The tables are not arranged for this latter purpose, however, and the labor involved is excessive.

In nearly all calculations, the writer finds it more convenient to obtain stress multiples instead of stresses, as such multiples can be more readily checked, and revisions, in case they are necessary, can be more easily made.

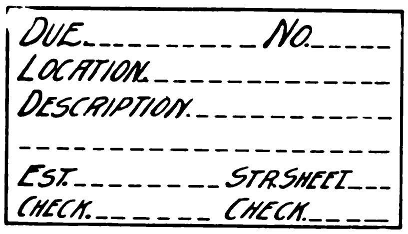
Much "lost motion" can be avoided and much liability to error escaped by having a fixed order for the parts of an estimate. The writer has long used such a system and finds that it economizes both time and mental effort. The "Order of Estimating" for railroad bridges will serve as a sample of them all. While intended as a guide in making up an estimate of weight after the calculations are completed, it will also serve fairly well as a guide in calculations.

There are many devices for lessening the labor of estimating, such as tables and standards; but the slide rule easily holds first place as a time saver. It is difficult to understand how the work of estimating, which a bridge

company is compelled to do, could be carried out without its use. For large work, or work requiring great accuracy, "Thacher's Calculating Instrument" is the best to be had. For other work the smaller rules will do, although a rule large enough to permit its divisions to be read with ease, and which requires no slide for the purpose of reading, is much to be preferred. For carrying out weights a rule that will multiply three numbers at one operation has decided advantages over the ordinary rule.

The only shortcoming of the slide rule is that it will not add. This defect is overcome by those machines designed primarily for adding, such as the "Comptometer," made by the Felt & Tarrant Manufacturing Company of Chicago, a cut of which is shown herewith. An estimator will not use one of these machines steadily enough to acquire the speed claimed by the manufacturers, but he will be enabled to save one-third of the time used in making summations, while the saving in nerve force, leaving him better fitted for the following work, is doubtless more important than the saving of time.

For a record of calculations, two general methods are used. One is to make the calculations on blank sheets, to be attached to the estimate and filed with it. The other is for each calculator to make all his calculations



consecutively in a book. Each system has its advantages. The writer prefers the book method for bridge work use, as it prevents the estimates from becoming too bulky and permits reference to the calculations independent of the estimate. If books are used, they should be of good paper, paged, well bound to open flat, and should show name of calculator and date of first and last estimate on the outside. The pages should be headed with the name of bridge or other structure, and the principal dimensions in form to readily catch the eye. Only one structure should appear on a page, unless the book is to be kept indexed. As a compact form for stating a highway bridge, the following has been found useful:

$200\times24+6+6\times2600$ Thro Pratt H. W. w. fl.

If only one sidewalk is required, the fact is easily indicated by dropping one of the sizes in the description; while if one sidewalk is required, but provision is to be made for a second walk, the fact may be indicated by inclosing one of the sizes in parentheses.

Blank forms for setting down work have an important bearing upon the cost of an estimate. The paper should be well sized, super-calendered, and thick enough to avoid any great tendency to curl when used. It should be no thicker than is necessary to secure these results, as excessive thickness fills up the files too rapidly. A paper with either a blotting or a sandpaper surface should be avoided. Any difference of cost

THE YOUNGSTOWN BRIDGE CO.

ORDER OF ESTIMATING

RAILWAY BRIDGES

TRUSS MEMBERS:– WEB DIAG'S.
WEB VERT'S.
BOT. CHORD
TOP CHORD

TOTAL TRUSS MEMBERS.
PINS ; PIN NUTS
SHOES
MASONRY PLATES
ROLLERS AND FRAMES
INT. FLOOR BEAMS
END " "
INT. STRINGERS
END "
STRINGER PEDESTALS
" CROSS FRAMES
" LATERALS
BOT. LATS } —— ←→ OR ANGLES
TOP " } WING PLS.-PINS-HITCHES
PORTAL RODS.-PINS.-RIV. BRACING
DIAG. RODS-PINS – RIV. "
PORTAL STRUTS
PORTAL KNEES
TOP STRUTS
SUB "
TOP STRUT KNEES
TOP AND BOT. STRUTS.-DECK BRIDGE

BOT. END STRUTS
LONGITUDINAL STRUTS
CASTINGS
LEAD s(EQUIVALENT)
BOLTS

TOTAL IRON AND STEEL

TIMBER–...FT. B.M. FURNISHED BY–
" PLACED BY–
TIE PLATES
SPECIFICATIONS
PAINT; SHOP AND FIELD
MATERIAL
REAMING
INSPECTION
TRANSPORTATION
HAUL
REMOVAL
ERECTION; HEIGHT TO MUD
BID F.O.B. OR ERECTED
CHECK
FORFEIT
TIME OF COMPLETION
BID DUE
MASONRY CHANGES

in its favor will be lost many times over in the increased cost of using it. While the form to be used must depend largely upon the class of work to be turned out, the three forms shown in Fig. 5 are believed to be an improvement upon the forms in common use. Form number one, shown at the top, is intended for the first sheet of original estimates, while form number two, shown in the center of the cut, is intended for all after the first sheet. Every sheet has provision for date and initials of the estimator. Space is left for binding without obscuring the title of the estimate. The space for sketch is left blank, as the sketch can then be drawn with small T square and triangle in half the time necessary to draw it on a quadruled surface. The column headed "number" is increased to allow of a number and name of member; the central space for "make-up" is subdivided to facilitate the record of gross and net areas, as well as the material of each member, while the columns for "No.," "length," and "weight per foot," are placed in the order in which they oftenest occur to the mind of the estimator. Form number two is the same as form number one, omitting the sketch and general heading. This form does fairly well for beams and all parts of a structure other than truss members and girder flanges, by disregarding the headings of all but the first of the left hand columns, and using the vertical lines as places of beginning for the description of main and subordinate items of the member in question. As far as possible, those items which need to appear on the strain sheet, should begin on one line, while all secondary items or those which do not need to appear on the strain sheet should begin a line to the right. Form number three, shown at the bottom of the cut, is intended for estimates of weight from plans furnished by the intending purchaser. Features of this form are the increased size of the column for name of member, and the addition of the column for short description, such as Top Flg., Bot. Flg., Web, etc., which greatly adds to the clearness of the estimate and reduces the labor of checking to a minimum. The writer has found that the use of this column repays many times the time taken in its use. The columns for weights are provided with ( ) and [ ], permitting the separation of more than six classes of material by simply surrounding part of the items with a ( ) or [ ], as the case may be. A necessary feature of any weight column is the distinct division of the spaces into columns of three places each.

Details of girders and similar work are best listed in the body of the estimate. For truss members, details are conveniently recorded as a per cent of the weight of the member for bridges, and as a per cent of the weight of the truss, exclusive of details, for roof trusses. This method has considerable advantage in point of time, and can be made as accurate as any by a little quick sketching on pad paper. This method has the great advantage of giving the weight of each member complete at a glance, which is important in checking cantilever work and in considering erection.

The value of an estimate for reference depends largely on the way it is made, and upon the facility with which it can be found. Every sheet should contain name and date and kind of material. If the structure be a truss, the weight of the truss members should be given separately. As noted above, a clear sketch is indispensable when an estimate is to be used for reference.

As a means of keeping account of pending work, the following scheme

Form 1, 1-1-89, 3M.

Sheet Nº ...... **THE YAARMOUTHE BRIDGE COMPANY.** ....189...

Estimate for ....

Span C.	Span E.		Iron & St.			Timber
Roadway Clear	Depth C. B.	Loads per foot	Wood & Track			
Sidewalk Clear	Width C.					
Capacity Trusses	Panels C.		Live Load			Joist
Capacity Floor		Panel load one truss	Total Dead			
Specifications			Total Live			

Members	D.L.	L.L.	Total	Unit Stress	Req. Area	Comp. Memb. ...... Eyebars	Beams ...... Lat. Angs.	Joist ...... Lat. Rods	Actual Area	Nº	Lgth.	Wt. Ft.	Total Weight.

Form 2, 1-1-89, 3M.

Sheet Nº ...... **THE YAARMOUTHE BRIDGE COMPAHY.** ....189...

Estimate for ....

Members	D.L.	L.L.	Total	Unit Stress	Req. Area	Comp. Memb. Eyebars	Beams Lat. Angs.	Joist Lat. Rods	Actual Area	Nº	Lgth.	Wt. Ft.	Total Weight.

Form 3, 1-1-89, 3M.

THE YAARMOUTHE BRIDGE COMPANY.

Estimate for ....

....189...

MEMBER	Nº	SIZE	LG.	WT. FT.	DISCRIPTION	WEIGHT ( ) ( )	( ) ( )	( ) ( )	( ) ( )	( ) ( )	( ) ( )

has been found useful: A board is provided with grooves for about forty cards such as are shown herewith. These cards are numbered consecutively, and a card is filled out for each piece of work as it comes in. These cards can be arranged on the board in the order of the dates. The items at the bottom of card are for checking off the progress of the work until the strain sheet has been finally checked. These cards can be filed when the work is out, and so form a record of the work that has passed through the estimating department.

The above methods are not suggested as the only ones possible, but merely as some of those which have proved valuable—most of them after years of actual use. They are submitted in the hope that they may prove of service to those engaged in similar work. No amount of system can take the place of experience and good judgment, but proper system will leave these qualities free to express themselves in better designs and less expensive estimates.

E. M. Scofield,
Asso. M. Am. Soc. C. E.

CHEMICAL AND PHYSICAL CONSTITUTION OF STEEL*

THIS is a subject which our Institute has made peculiarly its own. In the first volume of its *Transactions* the analysis of steel received attention, and every subsequent volume has borne witness to the acuteness and industry of our members in the investigation of this subject. The keynote was struck, in this as in so many other lines of progress, by A. L. Holley, in his paper on "Tests of Steel," read at the New York meeting of February, 1874—an essay which may rank as a classic by reason of its elegant form, logical force, and clear prevision of all the bearings of its theme. Taken together with the brief report of the discussion which followed it (in which Dr. Drown emphasized the effects of heat-treatment and mechanical handling, and Dr. Sterry Hunt the importance of minute variations in chemical composition, and of possible isomeric and allotropic conditions), it constitutes, after the lapse of twenty-three years, an admirable and adequate introduction to the long list of technical papers which have succeeded it.

Three years later came the epoch-making papers of Dr. C. H. Dudley on the relation between the chemical composition and physical properties of steel rails, which, with the voluminous discussion they evoked, constitute a special volume, published by the Institute, and full of useful suggestions. If Dr. Dudley could be induced to resume this investigation, he would doubtless be able to solve many points still uncertain or disputed.

But I cannot undertake to review the history of this subject, as represented in our *Transactions*—still less to restate all the contributions to it which have been made in books or in papers before other technical societies, since the initiative was taken by the Institute. My more modest purpose is to indicate, by a limited summary, the various steps in the discussion of a particular phase of the inquiry to which, in previous papers, I have devoted some attention. I mean the attempt to find empirical rules by which (due allowance being made for heat-treatment and mechanical manipulation) the tensile strength of steel may be predicted from its chemical analysis.

The provisional establishment of such rules would be useful to producers of steel as furnishing a valuable guide in practice, and to consumers as enabling them to procure intelligent specifications. For the purposes of scientific inquiry, on the other hand, it would be merely a preliminary step in the inductive process of discovering from accumulated observations the ultimate law. That is, it would be simply an arrangement of the vast body of observed facts which would facilitate a further induction from them. I think this point has been misunderstood by some authorities. Nobody pretends, for example, that the effect of each element in steel is exactly represented by an arithmetical addition to, or subtraction from, the tensile strength of the steel. The effect of other elements present, in modifying the effect of the one under consideration, is admitted. Nor is it pretended that, after such modification, a formula expressing the real law could be expressed in terms of simple addition or subtraction. If mathematically

*Trans. Am. Inst. of Mining Engineers.

expressible at all, such a comprehensive formula would doubtless involve complicated functions, high powers, etc. Meanwhile, if the ultimate law is ever to be discovered, empirical arrangements and summaries of the facts are the necessary preliminaries to such a discovery, and should not be despised by theoretic investigators. Such empirical rules I have in former papers set forth. Others have suggested other values for the different elements involved. I have no disposition to insist upon mine, which, though based upon numerous careful observations, and proved by many subsequent tests to be approximately reliable in practice, are still open to correction, and will be unhesitatingly withdrawn whenever any others shall be shown to fit observed facts more closely.

I may here remark that the suggestions of other experts in this line, from Dr. Dudley down, have, so far, involved the same assumption as my own, namely, that of a simple arithmetical form.

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In the latter part of 1885, Mr. Joseph Stokes, superintendent of the New Jersey Steel and Iron Company, gave me the following easy rule for getting the ultimate strength of steel: "Take 50,000 pounds per square inch as representing the strength of iron, and add to this 1,000 pounds for each .01 per cent of carbon in the steel."

I applied this rule with fair results in 1886-87 to the Clapp-Griffiths steel, manufactured by the Pottsville Iron and Steel Company. I have no doubt that Mr. Salom also had fair results at Chester in using a lower value for iron, and the same addition for carbon, his being open-hearth steel, low in phosphorus; but in each case I think the addition for carbon was too high, and included part of the effect of the manganese present.

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Prof. H. M. Howe, after giving the results of different investigators, and some of his own, states:

"While we cannot accurately quantify the effects of carbon, I believe that for ordinary unhardened merchantable steel, the tensile strength is likely to lie between the following pretty wide limits:

Carbon. Per cent.	Ultimate Strength. Lbs. per sq. in.	Range of Variation. Lbs. per sq. in.
.05	50,000 to 66,000	16,000
.10	50,000 to 70,000	20,000
.15	55,000 to 75,000	20,000
.20	60,000 to 80,000	20,000
.30	65,000 to 90,000	25,000
.40	70 000 to 100,000	30,000
.50	75,000 to 110,000	35,000
.60	80,000 to 120,000	40,000
.80	90,000 to 150,000	60,000
1.00	90,000 to 170,000	80,000
1.30	90,000 to 115,000	25,000

He further sums up the whole matter as follows:

"In the present state of our knowledge it seems probable that the conditions in a solidifying steel ingot, and perhaps in many other alloys and similar compounds, resemble those in a solidifying crystalline rock. For we find that the chemical condition of the components of the solidified steel and the size and probably the shape and arrangement of its individual crystals are affected according to unknown laws by changes in its ultimate

composition, and by the conditions which precede and accompany its solidification and cooling. . . .

"The influence of the conditions of cooling on the structure of steel is readily recognized. Slow, undisturbed cooling induces coarse crystallization; if the metal be vigorously hammered during slow cooling, the structure becomes much finer; if the cooling be sudden, extremely fine structure results. That other and now unguessed conditions profoundly alter both the mineral species and the structure of steel, and that changes in ultimate composition modify both species and structure of steel, as of crystalline rock, in most complex ways, is indicated by the utterly anomalous relations between the ultimate composition and the mechanical properties of steel. This anomalousness, which has puzzled so many, is readily explained by the close resemblance between the conditions of the formation of rock and of ingot, which not only shows us why we do not discover these relations, but that in all probability *we never can* from ultimate composition. The lithologist who attempted today to deduce the mechanical properties of a granite from its ultimate composition would be laughed at. Are our metallurgical chemists in a much more reasonable position?

"The complex way in which slight changes in ultimate composition may induce disproportionate changes in the proximate composition of the mineral species making up the solid steel, and through them its mechanical properties, is readily seen on reflection. If between the elements of the molten mass there exists a certain balance which just permits the formation of certain compounds during solidification, the introduction of a minute quantity of a certain element, say manganese, might just upset this balance and give rise to the formation of quite a different set of compounds, which might have radically different effects on the properties of the metal. While, were the original composition somewhat and perhaps but slightly different, then the addition of the same quantity of manganese might not in the least alter the kind or proportion of the different mineral species which make up the solid mass.

"If, pointing out that .02 per cent phosphorus sensibly alters the ductility of steel, you ask how this effect can be due to so minute a quantity of a simply intermingled mineral, I answer: (1) That we have just seen how minute changes in ultimate composition may profoundly alter the proximate composition. One per cent of salt distributed through gneiss would destroy its weather-resisting powers; 5 per cent of mica would give it strong cleavage; so 5, or even 1 per cent of a mineral whose presence in steel might be due to an addition of say .02 per cent of phosphorus, might profoundly alter its properties. We note among the hydro-carbons compounds whose physical properties differ greatly, yet whose ultimate composition is very similar, nay even identical. (2) That if 0.0002 per cent of iodine gives starch liquor a perceptible color it is not surprising that 100 times as large a quantity of phosphorus should perceptibly affect the properties of the iron matrix with which we may fancy that it directly combines. (3) That even so minute a quantity of phosphorus as .02 per cent may so affect the conditions of solidification, for example by altering the fluidity of the matrix at some critical temperature at which crystallization occurs, as to greatly affect the size, shape and mode of arrangement of the crystals of some of the minerals present, and of the matrix itself.

"If now it is asked why, if these so-called minerals form in steel during solidification, we never see them, I reply: (1) That the component minerals of many crystalline rocks are only discernible under the microscope, and even then only because they happen to be more or less transparent, to differ from each other in color, and to have crystalline forms which have been accurately determined by the study of large crystals; (2) that we have hardly begun to look for them in steel; (3) that under favorable circumstances we do find what appears to be distinct minerals in steel (graphite Fe_3C, TiC in definite crystals), and to so great an extent as to render it probable that these or similar minerals usually exist, but that, being opaque, so nearly alike in color, and in such minute and uniformly distributed particles, they escape observation. In considering segregation, we shall see that when steel contains considerable quantities of manganese, phosphorus, sulphur, etc., what are probably distinct minerals, perhaps even of definite chemical composition, form, now concentrating in the center of the ingot, now liquidating from its exterior according to the existing conditions.

"If these views be correct, then, no matter how accurate and extended our knowledge of ultimate composition, and how vast the statistics on which our inferences are based, if we attempt to predict mechanical properties from them accurately, we become metallurgical Wiggenses. For while we may predict that siliceous rocks will usually be vitreous, July hot, April rainy, and phosphoric steel brittle, yet when we go farther and predict accurately, we state what is not inferable from our premises. It may, and sometimes does, snow in July; Christmas may be warmer than Easter; the more siliceous may be less vitreous than the less siliceous rock, and the more phosphoric steel tougher than the less phosphoric one.

"And here it may be observed that the intimate knowledge which the public and many non-metallurgical engineers attribute to metallurgists, as to the effects of composition on physical properties, has, I believe, no existence in fact. Many steel-metallurgists persuade themselves, from wholly insufficient data, that they have discovered the specific quantitative effects of this or that element; in other, and I trust fewer, cases, in metallurgy, as in medicine, the charlatan feigns profound knowledge, dreading the effect on his client of acknowledged, though unavoidable, ignorance. Many an experienced steel-maker has confidently assured me of such and such specific effects, producing, when challenged, a few analyses unconsciously culled from those which opposed his view, and shown, on comparison with a larger number, to be without special significance.

"When we confront him with cases which upset his theory, he calmly replies that if we had only determined the sulphur as well, all would have been clear. If, by bad luck, this, too, is known, he thinks, probably, that nitrogen or carbonic oxide may affect matters; or, possibly, he attaches great weight to oxygen, which he can always fall back on, triumphantly remarking that when we can determine this element the problem will be solved. . . .

"By what methods ultimate composition is to be determined is for the chemist rather than the metallurgist to discover. But, if we may take a leaf from lithology, if we can sufficiently comminute our metal (ay, there's the rub!), by observing differences in specific gravity (as in ore-dressing), in rate of solubility under rigidly-fixed conditions, in degree of attraction by

the magnet, in cleavage, luster, and crystalline from under the microscope, in readiness of oxidation by mixtures of gases in rigidly-fixed proportions and at fixed temperatures, we may learn much.

"Will the game be worth the candle? Given the proximate composition, will not the mechanical properties of the metal be so greatly influenced by slight and undeterminable changes in the crystalline form, size and arrangement of the component minerals so dependent on trifling variations in manufacture as to be still only roughly deducible."

There is certainly very little here to encourage one in continuing the investigation. But since 1890, when Mr. Howe wrote the above, there have been great advances made in the methods of investigation, and our actual knowledge of steel has been increased. We also understand better the effects of the heat-treatment of steel, and he will, I think, agree in that the case is now not as hopeless as it formerly appeared.

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In a former description of my work of 1892, I said:

"Before attempting to investigate the effects of carbon, phosphorus, etc., on the ultimate strength of the steel, I had to find out how the ultimate strength was affected by the finishing temperature in rolling. This varies with thickness and width of plates, even when great care is taken to control the same. By rolling parts of the same heat into plates of different thicknesses the following values were arrived at. Assuming a three-eighths-inch plate under seventy inches wide to give normal results, we have corrections for size of plates shown in the following table:

CORRECTIONS FOR SIZE OF PLATES.

Thickness of Plates. Inches.	Up to 70 in. wide. Tensile Strength. Lbs. per sq. in.	Over 70 in. wide. Tensile Strength. Lbs. per sq. in.
$\frac{3}{4}$	—2000	—1000
$\frac{11}{16}$	—1750	— 750
$\frac{5}{8}$	—1500	— 500
$\frac{9}{16}$	1250	250
$\frac{1}{2}$	—1000	— 0
$\frac{7}{16}$	— 500	+ 500
$\frac{3}{8}$	— 0	+1000
$\frac{5}{16}$	+3000	+4000

"On this point my results are not very satisfactory, but during the investigation the importance of controlling the temperature at which the plates were finished was brought out forcibly."

And, in another part of the same paper, I observed:

"When rolling heavy steel plates, trouble is often caused by finishing them at too high a temperature, which gives a material with crystalline fracture, poor reduction of area, and poor bends. In order to guard against this and control the finishing temperature we use very light draughts in rolling, and produce as good results in heavy plates as in the light ones. Too much importance cannot be given to the heat treatment of steel. Prof. H. M. Howe's experiments on the subject are of the greatest value, and it is to be hoped that they will be continued on a larger scale, in connection with the work of rolling and forging."

On starting my investigation at Pottstown I gave carbon a value of 1,000 pounds and then decreased it to 900, 800, etc., but found that I had to take phosphorus into account; and I worked for some time with carbon

and phosphorus, giving each the same value and different values, and with different bases for the strength of pure iron, from 40,000 pounds upward, but could not get results that were satisfactory to me. I then gave a value to manganese, and soon found much improvement in my work. In order to investigate the matter more thoroughly, I recorded each test on a separate card, so as to facilitate grouping the tests under any given element. For instance, taking .15 per cent, and placing all the tests of that carbon in one pile, I eliminated the effect of carbon in that particular lot of tests, as far as the differences were concerned between the tests; and, by giving each of the other elements a value, I tried to account for these differences, and proceeded in the same manner in grouping the cards under other elements. Thus the values were arrived at, which I gave in my first paper, in 1892. But after this, as the number of tests increased, I found that by giving sulphur a value the results were improved; and my tables allowing for sulphur were given in a paper before the International Engineering Congress, at Chicago, in August, 1893. I found, early in the investigation, the importance of making a correction for the thickness of the plates, and my original 480 tests, with the estimated ultimate strength corrected for size, are given in detail in the latter paper, in which I said:

"In basic open-hearth steel, we have deducted 2,100 pounds from the estimated ultimate strength; this has given fair results, but the amount of deduction may have to be modified in using the new table. . . .

"From the results obtained, I believe that I am safe in saying that in all rolled steel the quality depends on the size of the bloom, or ingot, from which it is rolled, the work put on it, the temperature at which it is finished, and the chemical composition of the steel; that is, a table of this kind could be used for beams, angles, bars, etc. For instance, a six by six by three-eighths-inch angle, with a given chemical composition, might give 4,000 pounds higher ultimate strength than indicated by my table; but by making this allowance, the table could be used to advantage to show what ultimate strength another heat of steel with different chemical composition would give if rolled into the same sized angle. I trust that this point is clear, and that some of the shape mills will take the matter up and let us hear from them."

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Mr. Albert Sauveur, in 1893, laid down an interesting and important series of propositions concerning the effect of heat-treatment on the molecular structure and composition of steel.

While in Chicago, in that year, I saw the importance of having some definite plan for our discussions on the physics of steel. In order to avoid the necessity of going into many details, and explaining from time to time that we understood the bearings of many points on the matter, I took this subject up with Mr. Sauveur and Professor Howe, who were much interested and saw the importance of it. Mr. Sauveur took my rough plan and enlarged it, and his suggested lines for discussion were submitted to Professor Howe, who framed the final schedule, as given.

I refer to this matter at the present time because Mr. William Metcalf, in his discussion of Mr. Cunningham's recent paper before the American Society of Civil Engineers, treats the subject as though we had all overlooked the changes in the physical tests of material produced by heat-

treatment. This is rather discouraging, after the consideration that has been given to these very changes by most of us, and the plea made from time to time for more experiments on ***the heat-treatment of steel in connection with work.***

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Mr. Metcalf himself has recognized, and, indeed, proved, with unsurpassed clearness, both in theory and in practice, the importance of chemical composition, particularly as regards carbon. WILLIAM R. WEBSTER.

(To be continued in May Number.)

MEASUREMENTS FOR GRANITE VIADUCT *

DESCRIPTION.—The viaduct known as the "Granite" viaduct is on a change of line of the N. P. R. R., about one mile east of Granite, Idaho. The bridge is made up of a series of steel towers and spans, a thirty foot girder resting on each tower and sixty foot girders connecting them. The foundations are to be of granite, first-class bridge masonry, consisting of two piers at either end of the bridge, and pedestal foundations for each corner of towers. The viaduct will be 1167.07 feet long. It crosses one of a series of lakes extending from Pen d'Oreille river south to Granite. The lake at bridge location is 160 feet wide, surface of water 107 feet below top of bridge. On east side of the lake, ground rises ninety feet in a horizontal distance of 150 feet. On west side of lake ground is moderately flat for 300 feet, while at the west end of bridge the contour of ground is broken, both in direction of bridge and at right angles to its center line. The formation of ground is excellent for good foundations, having on top two to four feet of earth and decomposed granite, below which a solid granite bottom is reached; the formation of the country whence name of town, and bridge under construction. The formation as given above is true with exception of three pedestals, which are in the edge of marsh formation, and may possibly require piling. The soundings taken of the lake, show thirty feet of water at deepest point, with a rock bottom, covered with five to fifteen feet of wash sand or decomposed granite from sides, and decayed vegetation. The lakes are fed by springs and melting snow, in surrounding mountains, and surface of water in same varies but four feet, 2161.0 above the sea level being high water elevation, 2157.0 low water mark.

Thus far this article has been of a descriptive nature, the better to present the subject under consideration, "Measurements for Granite Viaduct."

The subject will be presented under the following heads, in order noted: 1. Methods of Measurement. 2. Instruments. 3. Check Measurements. 4. Computations. 5. Results.

METHODS OF MEASUREMENTS.—Before discussing this question, allow the problem to be presented. For purposes of future location of some twenty-six sets of pedestals and two piers, upon first of which are to be erected steel towers, a distance of 1,189 feet horizontal distance is be accurately determined. In this distance the contour is quite broken, with an extreme fall and rise of 107 feet.

For ordinary purposes, a steel tape with plumb-bob for "breaking" down slopes would be used. In this case, however, the results would not be accurate enough. The ground was first measured for profile purposes, and the distance was over three feet longer than made afterward when more accurately determined. As a substitute for tape and plumb-bob, wooden bars with level bubble attachment, all carefully graduated and adjusted, was suggested. These bars were to be used for horizontal measurements, and plumbing down. This plan eliminates and controls the uneven elevation of end of tape, and also sag in tape, but is objectionable because of necessary

*From Report of Illinois Society of Engineers and Surveyors.

short measurements, and great number of them increasing the possibility of error.

A second method suggested for this work, by J. R. Stephens, assistant engineer in charge, was to measure slope distances with a tape, vertical distance between points with a level and rod, and compute the horizontal distance. The advantages of this are long distances, removing objections of a large number of short measurements, also the error arising from failure to have tape or bar level, is eliminated. This method is used by the Coast Survey, I understand, for measuring base lines.

A third method (used as a check measurement) is by triangulation.

The principal error to be guarded against in the second and adopted method, is that arising from sag of tape, or difference in length between a straight line, and the catenary curve which the tape unsupported would assume. To eliminate this, stakes or hubs were driven every eight feet, and sawed off to a straight line connecting points, between which distance was being determined. At places it was necessary to excavate two feet or more, and in others build up as high as ten feet. Upon these hubs or stakes, boards, 1 by 8 inches, 16 feet long, were placed, and tape laid on board incline thus constructed. The stakes controlling their distance apart.

As the distances determined were afterward to be used in location of piers and pedestals, the points between which measurements were taken were made as permanent as possible. Hard wood hubs four inches in diameter were driven with a heavy maul into the decomposed granite, sawed off, a sixteen penny wire nail driven down to the shoulder of the nail, and two fine lines filed on head of nail, one in line of bridge, and a second at right angles, all measurement being taken from the intersection, which was also used as transit point. If the work were to be done another time, some knife edge nails would be procured, if not on the market have them made. They should have a shoulder so that they can be driven and not destroy the knife edge. A tape can be held to such an edge, more easily than on a head of a nail. After all preliminary steps were taken, four men were used in taking measurements, one at the hind end of the chain to hold same with a steady pull, a second man to note when mark on tape coincided with marking on nail, two men at head end of chain, one holding same with a spring balance, giving tape a uniform pull (twelve pounds for all lengths of tape was used), and a second person who read off the measurements. Each of these measurements was repeated at different times by two separate parties, the mean of the four results, after the necessary corrections for temperature and length of tape had been made, being adopted as the true length. Two sets of levels were run over the work, the mean results being adopted. The levels run by two parties after pegging down 100 feet and up 100 feet checked to four thousandths of a foot. These same levels which had been run previously with a self-reading rod for bench check levels, were run with a New York rod, the result checking both at bottom and top of bridge within two hundredths. This is mentioned merely to illustrate what can be done by careful work with a self-reading rod. A record of measurements made by one of the parties is here inserted to show distances covered, and form in which notes were kept.

(Part of table referred to.)

MEASUREMENTS AT GRANITE VIADUCT "O"

November 27, 1891.

Point to Point.	HOUR.	Temp. Degrees	Tension lbs.	Remarks	Slope Dis.	Tape Cor.	Temp. Cor	Nov. 27 Corrected Dis.	Nov 29 Corrected Dis.	Average of Distance
T1 to T2	3 40 p.m	Nov. 29 42	12	Shadow	69′ 0″$\frac{24}{64}$	$\frac{6}{64}$	$\frac{6}{64}$	69′ 0″$\frac{12}{64}$	69′ 9″$\frac{9}{64}$	69′ 0″$\frac{10}{64}$
T2 to T3	12 50 p.m	Nov. 27 50	12	Clear	28′ 6″$\frac{48}{64}$	$\frac{2}{64}$	$\frac{1}{64}$	28′ 6″$\frac{45}{64}$	28′ 6″$\frac{43}{64}$	28 6″$\frac{44}{64}$
T3 to T4	3 20 p.m	Nov. 29 42	12	Shadow	68′10″$\frac{50}{64}$	$\frac{6}{64}$	$\frac{6}{64}$	68′10″$\frac{38}{64}$	68′10″$\frac{36}{64}$	68′10″$\frac{38}{64}$
T4 to T5	1 55 p.m	Nov. 27 50	12	Clear	110′ 9″$\frac{19}{64}$	$\frac{9}{64}$	$\frac{6}{64}$	110′ 8″$\frac{38}{64}$	110′ 8″$\frac{33}{64}$	110′ 8″$\frac{61}{64}$
T5 to T6	2 20 p.m	50	12	Cloudy	109′10″$\frac{19}{64}$	$\frac{9}{64}$	$\frac{5}{64}$	109′10″$\frac{5}{64}$	109′10″$\frac{7}{64}$	109′10″$\frac{6}{64}$

Tape corrected for shortage of 1-16 inch to 50 feet.
Temperature correction used 1-64 inch to 2 degrees per 100 feet.

A set of notes similar to the above was taken by a second party, and results recorded in the right-hand column, averaged to determine true length. In adopting a twelve-pound pull or tension on tape, for taking out kinks, etc., in tape, it was proposed to have a tension stronger than was really necessary, with the idea in mind that all errors or non-uniform surface made distance longer, which will be counteracted by extra tension on tape.

INSTRUMENTS.—A Heller & Brightley transit, graduated to minutes, was used, while it was susceptible of very fine adjustment, in order to correct possible errors in adjustment, all located points were double centered. A new Buff & Bergers level was used, tested for adjustment by dumpy level method before and after levels were run, and equal back-sights and fore-sights employed.

A New York leveling rod with quadrant target was employed. A diamond-shaped target would have been better. A New York rod is accurately graduated and could be compared with a tape, which, with the method of measurement used, was an essential factor.

As all bridge and masonry measurements are in feet and inches, fifty feet tapes with that graduation were furnished, which had been compared with a bridge standard tape. The tapes furnished were reported one-sixteenth of an inch short in fifty feet. No information was given as to what temperature or with what tension the original bridge tape measured fifty feet. Sixty degrees was adopted as a standard mean temperature, for which all tape readings were corrected.

No data was available to determine the question of tension or pull on tape. The effect on tension will vary with cross-section and temper or hardening of steel of which it is composed. A series of tests were made to determine the effect of tension. A tape manufactured by the Lufkin Rule Company, Cleveland, Ohio, was used on bridge work and in tests. Two fifty-foot tapes were clamped together and tests made for stretch up to a pull of forty pounds. These tests show a uniform increase in length of one-eighth of an inch per 100 feet, for every eight pounds increase of tension.

Further tests were made with an Excelsior fifty foot steel tape graduated to tenths, tension being given up to forty-eight pounds. This test gave a uniform increase in length of four-thousandths of a foot per fifty feet for each increase of eight pounds tension, or reducing it to same length of tape as in first test, a uniform increase of eight-thousandths of a foot per 100 feet for every eight pounds of tension; it will be noted that results are very much alike and show a like law of increase of length on account of tension.

From theory and experiment it is known that metals will stretch up to their elastic limit, when they receive a permanent set. Until these tests were made, however, I was not aware that the amount of stretch was appreciable. When a length of standard tape is given, a statement of the temperature at which it is standard, and the amount of tension required should accompany it.

The tapes used were subdivided to one-eighth inches, but readings were taken to sixty-fourths of an inch. By a little practice one can rely upon reading to that degree of precision. This is in harmony with level rod readings to one-thousandth of a foot, and simplified the tape and temperature corrections.

The distances measured were in majority of cases over fifty feet. To simplify and expediate matters, as well as lessen liability of mistakes, two tapes were fastened together with a small clamp made of two pieces of file, with a set screw for clamping. This clamp answered its purpose admirably, the two fifty foot tapes becoming practically a 100 foot tape. To test, that tape was clamped at right place, distances of twenty feet each side of clamp were measured and compared with forty feet of single tape. To get a firm, steady hold on tape small gunsmith's vises were used to grip same, and into which an ordinary spring balance was hooked to obtain a uniform tension. A 25-cent Fahrenheit thermometer for taking the temperature completed the list of instruments.

Checked Measurements.—A triangulation survey was made to check the distance as determined by method just described. The location being favorable a 700-foot base line was obtained nearly in middle of bridge, and about at right angles to its center line, almost equally divided on each side of the bridge. The length of base line was determined by same method as used in measuring main line bridge with same care and accuracy.

The angles formed by base line and bridge tangent approximated 30 and 60 degrees, the most favorable for accurate computations. The method of repetition was used in measuring angles. All angles were repeated until 360 degrees were turned off, when instrument was reversed and process duplicated, the mean result, divided by number of times repeated, being true angle. The purpose of covering one circumference was to eliminate errors in graduation. At the four points from which angles were measured (two ends of base line and bridge tangent) there were three angles measured, the sum of two of which equaled the third. By this check the maximum variation was five seconds, varying from five to two seconds. This was with an instrument graduated to minutes. All obstructions were removed and in one place a three-foot ditch dug for fifty feet, that sights might be obtained on nails over which transit was set in turn.

Computation.—All measurements were reduced to feet and decimals of a foot. For this purpose Carnegie's pocket companion contains tables for reducing inches and each sixty-fourth of an inch to decimals of a foot,

a more extensive table than found in Trautwine or the usual railroad field books. All distances were figured and checked by two persons working independently. Errors are liable, by a strange community of feeling, to be made in common if two persons figure together. In computing distance from triangulation data the angles were proportioned, that sum of angles of triangle was equal to 180 degrees. Care was taken to use such triangles that formula, that "sides are proportional to the sines of their opposite angles," could be used. This much simplified calculations. Searle's tables of Logarithms of sines were used, which, in common with like tables in kindred field books, are correct by interpolation to two seconds, up to the angles of 60 degrees, which is sufficiently accurate for this and ordinary purposes.

RESULTS.—By method of slope distances the length between the two points on bridge tangent was 1187.021 feet and by triangulation survey 1187.042, a variation of .021 feet (one-quarter of an inch) in 1187 feet, or a difference of one in 60,000. This result was considered very satisfactory, in fact it was better than anticipated. This work was done with the instruments and facilities usually at command of the average railroad engineering party. The determination of pier and pedestal foundation locations is the reverse application of what has been discussed.

Is it necessary to obtain such accuracy where the bed plate on every pedestal has one-half inch play around anchor bolts, and an inch is allowed for expansion on every ninety feet of bridge, as is the case with the Granite viaduct? If the error from the true length is uniformly distributed, possibly not, but in order to eliminate ordinary mistakes, and obtain the desired standard of accuracy, it is best and necessary to use every precaution and check. It takes but little more time or labor, the satisfaction derived from the best results is no mean object, the training and experience is invaluable from an engineering standpoint, while unlimited confidence is gained, that work of office, shop and field will check, unless some marvelous unaccountable error of a foot or more yet be made, which in the after work is the most probable error to guard against; however, this last uncertainty should not cast a cloud on the precise results already attained. "Sufficient unto the day is the evil thereof." E. I. CANTINE.

Timely Topics.

THE EVOLUTION OF THE IRON ARCH

If it be conceded—for the evidence is not altogether conclusive on the point—that the ancient Egyptians were practically acquainted with the principle of the arch, it must be equally admitted that they made little or no application of it. We use the word "practically" advisedly, because neither the Egyptians nor the early Greeks, to whom the arch was known, could have had any knowledge of its true theory. No information on this subject was extant, until the aid of the mathematician was available in the determination of the curve of equilibrium, and the resultant stresses upon the structure. There is abundant testimony to the truth of this statement to be found in the construction of the old vaults and domes in Assyria, Egypt, India and in the New World before the advent of the white man, and also in similar buildings of a considerably more recent date. None of these vaults or domes were built of voussoirs, or arch stone, radiating from a common center or centers. They were formed by the corbelling or gathering over of the horizontal courses, and were not true arches in the sense in which the arch is regarded in European architecture and engineering. There is no doubt that columnar architecture emanated from the Egyptians, who nevertheless made but very little real progress in it, and that both in that country and in Greece the horizontal type of construction was sedulously and closely adhered to. It would almost appear as if the inhabitants of the lands of the pyramids had some especial aversion from the curvilinear contour, as they never adopted a circular elevation or a circular plan. Even in comparatively modern times, they persisted in using large stones for their lintels and openings, to the utter neglect of the arched form.

The primitive or indigenous—if we may employ the term—style of architecture of any partially civilized people, must depend altogether upon the description of the material or materials which are in the first instance available for constructive purposes. Even is subsequently, as generally occurs, another material may be substituted for its predecessor, yet strong traces of the original style or type of construction will still be manifest in all the designs under the new *regime*. In Egypt, for instance, where, except in a few favored localities, large timber fit for building purposes is not procurable, while there is abundance of excellent stone, the influence and presence of the latter material are predominant. Again, in Syria and Greece, countries in which timber was plentiful, that material unquestionably dictated the lines of the style of architecture ultimately adopted; for when stone supplanted timber it was not difficult to detect in the stone column the general form and fashioning of the timber pillar. The fact that the Greeks built originally in timber will fully account for the difference between their light and graceful style of architecture and the heavy, cumbrous, columnar style adopted by the Egyptians. Whether timber or stone gave rise to architecture, in the general signification of the term, has always been, and always will be, a much-disputed question, with the solution of which we are not at present concerned. Not that we are indifferent to it, for we trust that we shall be able fully to demonstrate that one particular description of the iron arch is plainly evolved from one of timber.

It was the Romans who got the arch from the late Grecians, and practically introduced it to the notice and service of modern nations in its original forms of the semi-circle, the segment, and the ellipse. A further development of the same principle gave us all the other well-known forms, with the exception

of that of the horseshoe, which is the peculiar characteristic of Arabian architecture. Selecting as the prototype the ordinary modern voussoir stone arch, the transition from it to some of the first specimens of the iron arch was a simple, and almost an unavoidable sequence. The Sunderland bridge over the river Wear, was erected exactly a century ago, with a span of 236 feet, and in it cast iron voussoirs were used, five feet in depth and two feet in length in the direction of the axis of the bridge. It is a matter of engineering history that fifty years later, it was proposed to construct instead of the present tubular design, arches over the Menai Straits, built of hollow cast iron voussoirs nine feet in depth by four in length. It was proposed, in order to obviate the impossibility of erecting a scaffolding over the turbulent waters of the straits, to hold back the cast iron voussoirs in their places by tie rods extending from the piers to the abutments. In the erection of the bridge over the Wear half-a-dozen of the iron voussoirs were held in position in this manner.

The examples of cast iron voussoir arch bridges are rare, but one more may be quoted. It is that of the bridge of Solferino, which has a central span of 130 feet, and in which the cast iron voussoirs in the central span are hollow, and solid in the side spans. It might be supposed that as the primitive cast iron arch is apparently nothing but a mere copy, substituting one material for another, of its stone predecessor, it would behave under similar circumstances in precisely the same manner, and be subject to the same stresses as the older structures. But this is not the case, and there are several points of difference between them. One of the principal is that the stone arch is not supposed to be affected by any bending moment, that is, that provided the points of support are immovable, no deformation can take place unless the stresses become greater than the crushing strength of the material. On the other hand, an arch of cast, wrought iron, or steel, would, under the same conditions, undergo deformation long before the ultimate compressive or tensile strength of the metal was reached. The stone arch, moreover, is practically unaffected by changes of temperature, to which the iron arch is peculiarly susceptible, whatever its precise mode of construction may be.

To the cast iron voussoir arch succeeded in the order of evolution the cast iron rib type, but of a very crude and imperfect design. One of the best examples of this new development exists in Rennie's design over the river at Southwark, although it should be stated that the similar structure at Vauxhall over the Thames, on a much smaller scale, was erected some three years previously. It may perhaps appear ungenerous to speak deprecatingly of Southwark bridge, which for the last three-quarters of a century has borne without flinching the ever increasing burdens imposed upon it, and still holds its position as the bridge possessing the largest cast iron span in the world. But whether the idea of the simple rib be derived from the contemplation of a very thin voussoir arch, or taken from timber examples of curved roofs, the fact remains that the ribs in the bridge are nothing more than deep thin cast iron segments set up like planks on edge. The Chepstow bridge over the river Wye, which has five cast iron rib arches, furnishes another example, and the absence of flanges was a characteristic feature of the early specimens of the ribs of cast iron arches. It is true that some of these did possess small horizontal projections or fillets, as they might appropriately be termed, but they were, if regarded in the light of flanges, of about as much use to the ribs as the diminutive wings of an ostrich would be were the bird to attempt to fly. The next step in the process of development was the addition of flanges to the simple plank-like ribs. This advance was not made, however, at a bound, but was slow and gradual, and was no doubt due to the general introduction of the horizontal flanged girder. It is singular that with regard to the relative areas of the upper and lower flanges of arch ribs, the same mistakes should have occurred which distinguished the adoption of flanges in the old cast iron horizontal girders, only in a contrary direction. The modern cross section for the cast iron arch rib, both in England and on the Continent is one in which the upper and lower flanges are not only equal in area, but of the same, or very near the same, dimensions also. Before the iron rib could be evolved to this state of perfection, it passed through an intermediate stage in which the discrepancy between the equality of area of the two flanges was more or less very strongly marked. In the rib of the Standish bridge the lower flange is 9 in. x 1½ in., and the upper

only 3 in. x 2 in., while in the bridge over the Thames at Barnes, the area of the two flanges is in the proportion of 30 to 16, or almost as two to one. The absence of flanges, or a very partial use of them, is also noticeable in many examples of arch ribs in early continental bridges of this type. Another feature which was frequently to be observed in arch ribs when passing through the intermediate stage between the flangeless and the double equal flanged system was the introduction of a small bead or fillet at the center of the depth of the rib along the whole length of it, probably with the idea of stiffening it. In wrought iron arch ribs, stiffening strips, and often angle irons in addition, are rivited to the web of the rib; but the thickness of the latter is very much smaller than what it is in the cast iron specimen.

About the same time as ourselves the French engineers began to adopt the double equal-flanged rib. A good example is that of the St. Louis bridge, over the Seine. It has a skew span of 212 feet, and equal flanges 15 inches broad by 1¾ inches thickness. Among many excellent examples at home of this highly developed type of iron arch, we might quote the public-road bridge over the Medway at Rochester, with a central span of 170 feet, and the two well-known bridges over the river Trent, each having a single span of 200 feet. It should be here observed that in all the examples we have quoted, whether the rib be of the flanged or flangeless type, the principle of the arch is still preserved. Each segment, or length of rib, is in effect nothing more than a thin long iron voussoir. The joints of the segments radiate from exactly the same center as those of the voussoirs of a stone arch would do, of the same span and rise. If the length of the segment be increased until it becomes equal to the semi-arch, then the case becomes almost identical with that of a pair of inclined rafters meeting at an apex. There is another description of an iron arch, which, although the resistance of the point of support as a counter thrust is replaced by a tie, yet is an example of the true principle of that design. There is also a particular mode of constructing a timber arch, known as that of De l'Orme, in which the arch consists of a number of thin planks bent to the required form and placed one over the other until the necessary sectional area is obtained. The same operation is repeated, substituting iron plates for timber planks, in the horizontal parts of the flanges of all the modern wrought iron arches, which are thus clearly a development of the laminated timber arch. There is, notwithstanding, one point of difference between them worth noting. The laminated timber arch is a thing of the past; the laminated iron arch—or, in fact, the laminated iron girder—is a thing of the present, and, in all probability, of the future as well. As an example par excellence of the capabilities of the metallic arch, the Harlem River bridge may be selected. It has a pair of steel arches 510 feet in span, each consisting of six solid steel ribs. Although no doubt the open web arch was a direct consequence of the introduction of the open-web girder, yet it has by no means—except, perhaps, in roofs—supplanted its solid web rivals to the degree which has attended the substitution of the numerous open-web forms for the older plate system of construction. Of the many arch-ribbed bridges over the Thames, there is not one that has any bracing—or, in other words, is not solid throughout the whole cross-section. One of the finest specimens of the open-web arch is to be found in the St. Louis bridge over the Mississippi, which has three spans. The central is 520 feet, and the two side spans 502 feet each. Each span is composed of four ribs, and each rib is built up of a pair of steel tubes, spaced vertically twelve feet apart, and connected together by open web diagonal bracing. It is perhaps doubtful whether the braced arch should be included in our present category or not. It is not strictly speaking, a girder, for it exerts an oblique thrust against the points of support, and so far resembles its prototype, the stone arch. This particular type of arch or girder has not met with much success among engineers. There is a good example in the railway bridge over the Thiess at Szegedin, which consists of eight spans of 136 feet, and another carrying the Paris and Creil line over the Canal St. Denis. The latter structure has a single arch, 148 feet in span, and displays the distinguishing feature of this especial form of construction—that is, the blending or merging into one of the upper and lower flanges at or near the center. In fact, under certain conditions, each half arch, together with its spandrel, constitutes a distinctly separate rigid truss or framework.—*The Engineer.*

THE PROJECTS FOR GREAT BRIDGES

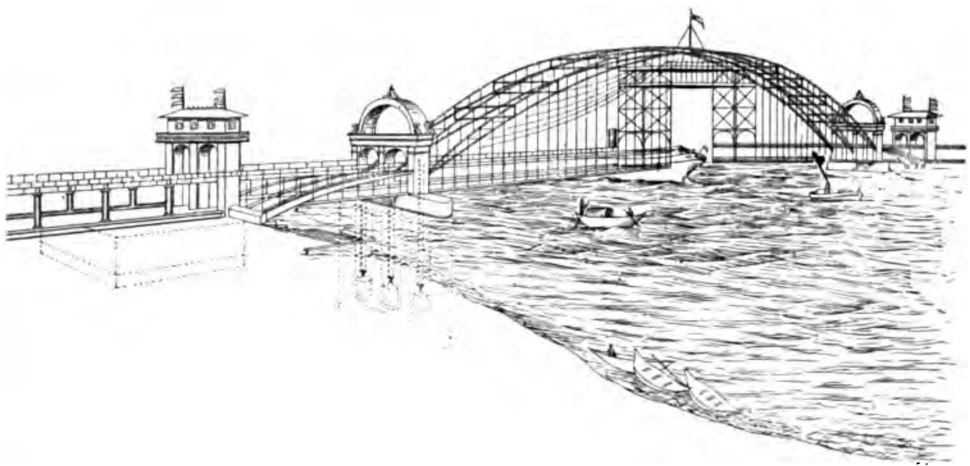
The projects for great bridges are called to mind by the illustration in this number of the proposed English Channel bridge, which is very much the most remarkable bridge ever proposed in a serious way. Whether it is ever constructed, it has already become a goal toward which engineers are working. The proposed designs for the great Forth Bridge, included several of the suspension type, which were rejected in favor of the cantilever, but now the trend of opinion is again toward the suspension bridge for long spans, with the use of either stiffening trusses, or stiffened cables.

The new East River bridge at New York is nearing the stage when the erection of the steel towers can begin, and a little later the placing of the cables and stiffening trusses will be commenced.

Hopes are entertained for the early realization of the project for a great suspension bridge over the Hudson at New York, which will have a span of about 3,000 feet, and with the cables on either side placed vertically one above the other and trussing between.

Draw bridges have been built of great length, exceeding 500 feet, and a very wide one was recently proposed, of the swinging type for eight railroad tracks over the Chicago Drainage Channel. After the contract was awarded, objections were raised by the railway companies, which resulted in a change to a bascule bridge. This is only in harmony with the recent practice which seems to be in the direction of some other type than the swing.

The most notable of designs for another type is the one prepared by Sir Bradford Leslie for a permanent bridge over the River Hooghly, at Calcutta, of which a sketch from *Indian Engineering* is reproduced. The central span or arch is 1,000 feet span, with two side half arches of 250 feet each, from the piers to the abutments, on the plan which was patented by the American engineer, Mr. Jas. B. Eads. The upper floor is to carry four lines of railway, and the lower floor a 40-foot roadway and two 7-foot sidewalks. The lift bridge at the center has a length of 200 feet, and raises to a clear headway of 120 feet above high water, being operated by counterweights in wells in the piers. The diagonal bracing of the arches was omitted in the sketch to avoid confusion. The lift platform is shown raised to its full height.



HOOGLY BRIDGE AS PROPOSED.

The scheme is a very remarkable one, and it is to be hoped that it may have an actual trial—there being much to commend it and many features of superiority over other well known types.

THE CONSTRUCTION OF STREET RAILWAY TRACKS IN PAVED STREETS

The Committee of the American Society of Municipal Improvements on Street Paving submitted a report at its last meeting relating to the best kind of rails to use for

street car tracks in paved streets, and to the best kind of pavement to be laid along and between the rails, and its proper maintenance.

This subject is one of much importance in bridge construction, and the conclusions arrived at are given in full:

"As to the form of rail, there is considerable variation and difference of opinion, though that most in favor among railway companies is the 9-inch side-bearing girder, weighing ninety pounds or more to the yard, though in several places where permitted by the law or the municipal authorities, the T-rail seems to be in favor, while municipal officers generally prefer a grooved rail. Considerable opposition has been manifested by the railway companies to the grooved rail, but when its use has been insisted upon, they have soon accepted the situation, and find that there is no difficulty connected with its use.

"Your committee is disposed to agree with the sentiment that asphalt and street railroad tracks are hereditary enemies, but is convinced that, with substantial track construction, and the proper kind of rail, an asphalt pavement can be maintained on both sides of the rail, where the traffic is light, and that, with the use of a toothing course along the inside of the rail where the traffic is heavy, asphalt can be used on railroad streets as well as any other material.

"After a careful consideration of the facts and opinions elicited by the letters received in response to their inquiries, and such personal investigations as have been made, your committee would report the following conclusions:

"Only the most substantial and permanent track construction should be permitted in important paved streets. The tracks should be laid upon a concrete foundation, metal crossties being substituted for wood, resulting not only in greater permanency, but saving depth of concrete and excavation.

"The best form of rail is the grooved girder, nine inches in depth where streets are paved with stone, and seven inches deep where paved with asphalt. In some cases, where streets are very narrow and vehicles are obliged to follow the tracks, the 9-inch side-bearing girder may be preferably selected stone blocks of granite or trap being laid along the inside of each rail, and at the same level as the head of the rail. On exceptionally wide streets, where the traffic is not heavy, and will occasionally cross the tracks obliquely, but not follow them, T-rails may safely be used.

"The pavement along the rails will depend upon that used on the remainder of the street. If the latter is of stone blocks, the pavement along and between rails should be the same, but in all cases should be of selected blocks upon a substantial concrete foundation, the joints filled with fine gravel and paving pitch. If of brick, the same practice should be followed, the joints along and between the rails being filled with similar paving pitch in whatever way the joints on the remainder of the street may be treated.

"On asphalted streets the asphalt may safely be carried up to the back of the rail, and if full-grooved rails are used, and the vehicular traffic is light, it may be carried entirely across the roadway. For heavy traffic, the spaces between the rails and tracks should be paved with selected granite or other hard, tough blocks, laid on concrete, with pitch and gravel joints. For moderate traffic, a toothing-course of carefully selected blocks, four inches wide, and varying in length from three inches, but in no case more than ten (10) inches long, should be laid along the inner side of the rails, whether grooved or side-bearing. These blocks may be laid in pairs of two long and two short, in which case the asphalt along them can be tamped more thoroughly.

"In all cases blocks next to the rail should be bedded in rich cement mortar, rather than laid upon a sand cushion. The spaces under the head of the rail should be filled with fine cement concrete, leaving a vertical joint between this filler and the pavement, whether the latter be stone, brick or asphalt.

"Openings made for repairs to track should be immediately restored before the stone blocks become injured, or the adjacent pavement or foundation disturbed. Such openings being shallow, this can always be done without danger of settlement."

ELECTROLYSIS OF THE BROOKLYN BRIDGE

Perhaps the most unexpected discovery made in connection with the great extension of overhead-conductor electric railways is that the return currents from the moving cars often seek buried metals, such as water and gas pipes, and, in more or less time, cause their destruction by electrolytic solution. The dangers to which buried pipes are thus subjected have caused the passage of strict municipal ordinances in the United States, and the matter has been made the subject of parliamentary legislation in the United Kingdom. So far, the injurious effects of these earth currents have been investigated with reference only to pipes, but the well-established injury wrought upon these is beginning to cause fears for the safety of certain other subterranean metallic structures. In a long paper read before the last meeting of the American Institute of Electrical Engineers Mr. A. A. Knudson gives the results of a series of measurements of electrical potential between various rails and pipes in the

borough of Manhattan, and concludes with some highly interesting measurements of electrical pressures at various points of the New York and Brooklyn bridge. These show that, while the bridge is probably in no immediate danger, the electrical condition of the anchorages will bear watching.

The measurements of potential show that all over Manhattan Island a slow destructive action is going on, embracing not only water and gas pipes, manholes, etc. but the vertical members of the elevated railway structure as well. It is demonstrated that the influence of an overhead trolley line of only ordinary activity extends for more than a mile, and that the whole lower end of Manhattan Island is permeated by earth currents having their origin in the extended overhead trolley system of Brooklyn. These currents seem to cross the East River by the bridge cables and to ramify through the pipes, etc., beneath the surface of lower Manhattan, finding their way back to Brooklyn at a number of points along several miles of the river front.

The cables of the bridge are anchored to heavy cast-iron plates imbedded in masses of cut stone masonry laid up with cement in the most substantial manner. The author concludes that, although these anchor plates are only a few feet above mean high-water level, and some 900 feet back from the waterfront on each side, there are no conditions present favorable to electrolytic action.

Just how this can be reconciled with the passage of a large current via the bridge from the Brooklyn side is not made clear. The fact that such a current does cross the river, and in sufficient amount to make itself evident over more that a square mile of the lower part of Manhattan, seems to be well demonstrated. Wherever the current leaves a metal in the damp earth—that is, where the metal is positive to the ground—there will be electrolytic solution. The amount of this is definite, provided the conduction from the buried metal is electrolytic, and not due to the specific conductivity of the materials in which it is buried. As the bridge anchorages are bedded in a mass of stone and concrete, only a short distance away from salt water, and as both these substances are fair insulators, it is reasonable to assume that the only way in which the current can leave the anchor plates is by electrolytic conduction through such water and salts in solution as may be present.

Should this be the case, the metal parts of the anchorage will inevitably be dissolved, unless the electrolytic action is stopped. Unfortunately the anchorages are not accessible for examination, so that no theory of what is going on can be put to the test; but certain simple preventive measures might well be taken, and, whether or not the danger is real, would certainly have no harmful effect. Another conclusion which Mr. Knudson draws is that there is absolutely no perceptible outflow of current from the new conduit railway systems in New York. While this fact is not unexpected, it is gratifying to know that actual tests demonstrate that there can be no possible elecrolytic action following the installation of a railway of this sort.—*Engineering Magazine.*

THE KORNHAUS BRIDGE AT BERNE

Nearly two years ago the commencement of work upon the great Kornhaus bridge across the valley of the Aar at Berne was noted, and now we have to notice the completion of the work as described in a very fully illustrated paper in the *Zeitschrift des Vereines Deutscher Ingenieure.*

The promontory upon which the old city of Berne was originally placed has long since been outgrown, and upon all sides of the loop of the Aar have grown up suburbs which require ready communication with the old town. The stone arch of the once famous Nydeck bridge was the first attempt to provide a high-level roadway, and this was followed by the railroad bridge, the Kirchenfeld bridge, and the present structure, which, since it extends from the Kornhausplatz to the Spitalacker, is known by the name of the former place; besides which there is the Lorraine bridge, as yet uncompleted.

The finished Kornhaus bridge does not differ materially from the description given in November, 1897, the total length of nearly 1,200 feet being composed of four arches on one approach and one on the other side, each of 118 feet span, and the one great steel arch of 407 feet clear span over the Aar. On each side of the river rises a masonry pier over a hundred feet high, the main arch

springing from the bases of the piers and the approaches extending from them to the banks between smaller piers.

Owing to the manner in which the ground beneath Berne and its surroundings is permeated with ground-water, much difficulty was experienced in securing satisfactory foundations in the sloping banks for the great piers, it being necessary on one side to excavate to a depth of more than ninety feet in the sliding moraine before a bearing in solid rock could be secured.

Many interesting details are given showing the manner in which the difficulties of construction and erection were overcome, and the whole work forms a good account of a form of bridge construction which is greatly in vogue at the present time.

The completion of this fine work leaves only the Lorraine bridge to be finished, in order that Berne may possess fine examples of both steel and masonry arches, and a visit to the capital of Switzerland will soon be a pilgrimage of instruction for all who are interested in this branch of engineering.—*Engineering Magazine.*

BASIC STEEL AND BASIC IRON IN ALABAMA*

The manufacture of basic open-hearth steel in Alabama began on the 8th of March, 1888, at North Birmingham. It was the first attempt at steel making in the state and this furnace was among the first basic open furnaces built in the United States, if not the first.

The enterprising character of the men composing the Henderson Steel and Manufacturing Company in undertaking at this early date to enter upon the production of basic steel when there was but one other establishment in the country, is deserving of the highest praise.

There was very little known about the basic steel then, for the development of the industry has been rendered possible during the last ten years. The Henderson Steel and Manufacturing Company lay, therefore, claim to have been the pioneers in an industry which has grown to very large proportions elsewhere in this country, and which now promises to be of increasing importance here.

*(From advance sheets of Iron Making in Alabama, by Wm. B. Phillips, second edition 1898.)

While the operations at North Birmingham did not attain the commercial success so well deserved by the faith and progressiveness of the promoters, technically the process even then was successful. In its essential construction and operation the furnace did not differ from those now used, for although what was known as the Henderson process was employed, yet there was no real difference between it and the more recent modifications of the basic open-hearth.

To the kindness of Mr. H. F. Wilson, the secretary of the company, the writer is indebted for some data concerning this furnace. It was of thirteen tons capacity, and made 200 heats before it was closed down. The maximum output in any one day of twenty-four hours was twenty-five tons, and about 1,600 tons of steel were made. The steel was sold as ingots, to the Bessemer Rolling Mill Company, Bessemer, Ala., for about $22 a ton, and they made most excellent boiler plate of it. Crellin & Nalls, Birmingham, manufactured boilers of it, and some of their work may now be seen in the grain mill of Mr. B. B. Comer, Birmingham.

Additional information in regard to the early history of steel making in Alabama is contained in a pamphlet entitled "Basic Steel. Report of committee on its successful and economical manufacture by the Henderson Steel and Manufacturing Company, North Birmingham, Ala., August 27, 1890."

Mr. Gogin was at that time manager of the steel company.

The committee reported that on August 19, 1890, there was charged into the furnace:

White Pig Iron from DeBardeleben Furnaces:	Pounds.
Bessemer, Ala.	15,000
Pit scrap	5,525
Miscellaneous scrap	4,514
Brown ore, 55 per cent iron	742
Spiegel	200
Ferro-manganese	200
Total metal	26,181

The quantity of fluorspar and limestone was not given.

The Yield of Metal was—	Pounds.
Twenty-four steel ingots	22,250
Pit scrap	1,510

The yield then was 85 per cent of ingots and 6 per cent pit scrap, and the loss of metal about 9 per cent.

The committee further reported that basic billets and slabs could be made for $22 a ton.

The analyses quoted were as follows:

WHITE PIG IRON

Silicon	0.43	per cent
Sulphur	0.149	"
Phosphorus	0.68	"
Manganese	0.10	"

BROWN ORE

Metallic iron	56.12	per cent
Phosphorus	0.34	"
Insoluble residue	4.99	"

LIMESTONE

Carbonate of lime	95.71	per cent
Alumina and oxide of iron	1.04	"
Silica	1.33	"

STEEL

Silicon	Trace	
Sulphur	0.06	per cent
Phosphorus	0.018	"
Manganese	0.29	"
Carbon	0.08	"

The writer made analysis, in 1890, of a sample of the first heat of basic open-hearth steel March 8 1888, which had been drawn out, under a hammer, and found its composition as follows:

Analysis of the first heat of basic open-hearth steel made in Alabama, at North Birmingham, March 8, 1888—

Silicon	0.023	per cent
Sulphur	0.014	"
Phosphorus	0.038	"
Manganese	0.144	"
Combined carbon	0.484	"
Graphitic carbon	0.095	"

The report of the committee also stated that the physical tests of the steel they examined were as follows (plate 3/8 sec. x 1 sec):

	4-In. sec. lbs.	8-In. sec lbs.
Ultimate tensile strength per square inch	48,110	48,460
Elastic limit per square inch	32,030	32,275
Reduction of area	54.7 per ct.	57.4 per ct.
Elongation	32.0 per ct.	28.0 per ct.

A sprue of the first group of ingots was forged into a bar one inch square, and was bent when cold with a sledge until perfectly folded. Not the slightest flaw could be detected at the fold.

Excellent razors and knives were also made of this steel, and some of them are still in use in Birmingham. It is, therefore, to be concluded that the first basic open-hearth furnace in Alabama, and one of the first in the United States, beginning operations in March, 1888, made excellent steel of native materials. The process was handicapped with white pig iron high in sulphur, and of irregular composition, as also by lack of experience on the part of the operators, and many other obstacles besetting a new enterprise, but the promoters had the courage of conviction, and went as far as their means would permit. They are entitled to and should receive the highest commendations for what they did, for they laid the foundations of the steel industry in this state. The times were not ripe for the commercial success of the enterprise then, and it was not until the middle of 1897 that they seemed to hold out promise of fruition.

The Jefferson Steel Company succeeded the Henderson Company, and operated the North Birmingham furnace in 1892 and 1893, making, perhaps, 1,600 tons of steel, under the management of Ernst Prochaska. The operations were suspended during the summer of 1893. Here the matter rested as to Birmingham, until 1897, for the crude experiments carried on under the Hawkins process at North Birmingham in 1895 cannot fairly be included in a historical sketch of the rise of the steel industry here.

The amount of basic open-hearth steel made at Birmingham, all of native materials, except as to spiegel, ferro-manganese, and fluorspar, up to July 22, 1897, would not exceed 3,500 tons, if, indeed, it is above 3,000 tons.

Basic open-hearth steel of good quality has been made at Fort Payne, the first operations dating from 1893, but details are lacking.

In 1897 the Birmingham Rolling Mill Company, which had been in successful operation for a number of years, and which of late had been buying steel billets in Pennsylvania, and rolling them into shape here, took up the matter. The citizens of Birmingham subscribed to the undertaking to the amount of $40,000, and the first basic open-hearth furnace went in July 22, 1897, being followed by the second on October 25. Both furnaces were designed and built by S. R. Smythe & Co., Pittsburg, Pa., with a capacity of thirty-five tons each to the charge. The iron used was the basic iron made at the Alice furnace,

within 200 yards of the mill. The quality of the metal has been and is now of an excellent quality, as the following analyses of the first 245 heats will show, in respect of chemical composition.

The chemical composition of the metal is given in the following tables:

Analyses of the first 245 heats of basic open-hearth steel made by the Birmingham Rolling Mill Company Birmingham, Alabama, from July 22 to December 31, inclusive, 1897.

SULPHUR

	Heats.	%
0.015 to 0.020	31=	12.7
0.020 to 0.025	69=	28.1
0.025 to 0.030	81=	33.1
0.030 to 0.035	33=	13.5
0.035 to 0.040	17=	7.0
0.040 to 0.045	8=	3.2
0.045 to 0.050	2=	0.8
0.050 to 0.055	1=	0.4
0.055 to 0.060	1=	0.4
0.060 to 0.065	2=	0.8
	245	

Average sulphur 0.028%

PHOSPHORUS

	Heats.	%
0.001 to 0.005	100=	40.8
0.005 to 0.010	49=	20.0
0.010 to 0.015	15=	6.1
0.015 to 0.020	16=	6.5
0.020 to 0.025	18=	7.3
0.025 to 0.030	13=	5.3
0.030 to 0.035	8=	3.3
0.035 to 0.040	5=	2.0
0.040 to 0.045	6=	2.4
0.045 to 0.050	3=	1.2
0.050 to 0.055	1=	0.4
0.055 to 0.060	4=	1.6
0.060 to 0.065	2=	0.8
0.065 to 0.070	1=	0.4
0.090 to 0.095	1=	0.4
0.095 to 0.100	1=	0.4
0.100 to 0.150	1=	0.4
0.150 to 0.200	1=	0.4
	245	

Average phosphorus..............0.012%
Average manganese.........0.45
Average carbon..............0.18
Average silicon..............0.008

It will be seen that in 181 heats out of 245, or 73.9 per cent, the sulphur reached a maximum of 0.030 per cent, while in 64 heats, or 26.1 per cent, it was above 0.030 per cent. In only 14 heats out of 245, or 5.6 per cent, was it above 0.040 per cent.

In a list of sulphur estimations in basic open-hearth steel, given by H. H. Campbell (Manufacture and Properties of Structural Steel, 1896, pp. 321 and 322), the number of heats examined was 973. Of these, 255 heats, or 26.2 per cent, showed a maximum sulphur of 0.030 per cent, while 618 or 63.5 per cent, gave sulphur above 0.030 per cent.

The conditions as to sulphur are then seen to be in the case of the Birmingham steel almost the reverse of those maintaining in the basic steel quoted by Mr. Campbell. In the Birmingham steel 73.9 per cent of the heats showed a maximum sulphur of 0.030 per cent, while in the steels quoted by Mr. Campbell, and presumably of Northern make, there were 63.5 per cent above 0.030 per cent in sulphur.

In the Birmingham steel there were 26.1 per cent of the heats with sulphur above 0.030 per cent, as against 63.5 per cent in the other steels.

Furthermore, in Mr. Campbell's steels were 143 heats out of 973, or 14.7 per cent, in which the sulphur was above 0.040 per cent, as against 14 heats out of 245, or 5.6 per cent, of Birmingham steel, and in Mr. Campbell's steels, there were 87 heats out of 973, or 8.9 per cent, in which the sulphur was above 0.050 per cent, as against 4 out of 245, or 1.6 per cent, in the Birmingham steel.

It is however, in respect of phosphorus that the chief obstacles were encountered and successfully overcome.

The sulphur may be considered an element whose maximum in the steel may be more easily controlled than that of phosphorus, especially when the pig iron used is low in sulphur. If the maximum sulphur in the pig iron is 0.050 per cent the removal of 50 per cent would cause the steel to carry from this source 0.025 per cent. But with phosphorus at 0.75 per cent in the pig iron, 86.6 per cent must be removed to bring the steel down to 0.10 per cent, the maximum allowable under most circumstances, while 93.3 per cent must be removed to bring it to 0.05 per cent.

Basic open-hearth steel has been made in Birmingham of pig iron, pit scrap, and ore, in which the phosphorus was below 0.050 per cent, and in some cases below 0.010 per cent. The phosphorus estimations given in the preceding lists are of steel made with various mixtures of pig iron and scrap and ore, and there is practically no difference between them. An examination of the list shows that 149 heats out of 245, or 60.8 per cent, gave a maximum phosphorus of 0.010 per cent, while 180 heats out of 245, or 73.4

per cent, gave a maximum phosphorus of 0.020 per cent. Putting the phosphorus limit in the very highest grade of basic open-hearth steel at 0.030 per cent, we find that 86 per cent of the heats showed a maximum of this amount, and in 40.8 per cent of the heats the maximum phosphorus was 0.005 per cent.

In the results given by Mr. Campbell (ut supra), we find that in 157 heats out of 973, or 16.1 per cent, the maximum phosphorus was 0.010 per cent, as against 60.8 per cent in the Birmingham steel, with a maximum of 0.010 per cent. In the Northern steels there were 770 heats out of 973, or 79.1 per cent, in which the maximum phosphorus was 0.020 per cent, as against 73.4 per cent in the Birmingham steel, with a maximum of 0.020 per cent. The percentage of heats in the Northern steels with maximum phosphorus 0.020 per cent is somewhat higher than in the Birmingham steel. In the Northern metal there were no heats in which the phosphorus was below 0.005 per cent, while, as before stated of the Birmingham steel, 40.8 per cent of the heats had maximum phosphorus 0.005 per cent.

Of the Northern steels there were 898 heats out of 973, or 92.3 per cent, with maximum phosphorus 0.030 per cent, as against 86 per cent in the Birmingham steel. But when one considers the number of the heats of Northern steel, in which the phosphorus is above 0.030 per cent, it is found that they are 75 out of 973, or 7.7 per cent, while the corresponding percentage in the Birmingham steel is 13.7, nearly twice as many.

Taking everything into consideration, however, with due regard to the newness of the conditions surrounding the production of steel in Birmingham, and the fact that the results here given are from many different mixtures in the furnace, we conclude that in chemical composition the steel compares very favorably with standard makes of Northern steel, and that the severest specifications could be successfully met.

The plates tested were 16 inches long over all, 8 inches long, and 2 inches wide between fillets, with a fillet radius of 1½ inches. They were pulled on a 200,000 Riehle testing machine, with automatic extensometer and electric registration, the elongation being afterward checked by measurements. Numerous other tests might be given, but it is thought that these will be sufficient to show the quality of the material made from the basic iron of the Birmingham district. Up to the 1st of May, 1898, 500 heats had been made and the two furnaces are now in active operations. The material is made into boiler and tank plates, fire-box sheets, rounds, flats, and squares, and is sold under specifications as to chemical composition and physical tests.

The following table gives the results of the examination of some basic open-hearth steel plates made by the Birmingham Rolling Mill, for elastic limit, tensile strength, elongation, and reduction. All the chemical analyses, as well as the physical tests, were made by Mr. David Hancock and the writer, in the Phillips Testing Laboratory, Birmingham.

Giving physical tests of basic open-hearth steel plates made by the Birmingham Rolling Company, 1897-1898.

Specimen of Plate Size	Elas. Limit, lbs. per Sq. Inch	Ten. Str., lbs. per Sq. Inch	Elongation in 8-inch, per cent	Reduction of Area per cent
5-16 inch	35,360	65,600	25.7	49.6
5-16 inch	34,720	62,440	27.2	52.6
5-16 inch	35,200	63,720	27.5	51.5
5-16 inch	33,300	58,290	26.0	49.6
5-8 inch	33,930	57,900	25.0	53.0
5-8 inch	28,900	53,680	32.5	51.0
5-8 inch	31,040	52,510	27.0	52.8
5-8 inch	32,360	53,390	31.7	56.5
7-16 inch	31,400	50,520	32.0	64.0
7-16 inch	32,360	50,650	30.7	61.6
7-16 inch	29,960	51,130	30.0	60.8
7-16 inch	32,790	53,960	27.2	57.4
7-16 inch	32,760	53,360	26.5	55.7
7-16 inch	32,260	53,420	30.5	58.0
1-4 inch	39,560	58,420	27.8	53.1
1-4 inch	41,450	57,260	25.0	54.9
1-4 inch	43,040	64,380	25.0	55.1
1-4 inch	43,470	63,310	25.0	50.6
1-4 inch	44,280	58,480	26.7	55.8
1-4 inch	44,850	57,490	26.0	54.9
1-4 inch	43,590	56,680	26.0	54.9
1¾ round	32,680	50,520	32.5	63.5
1¾ round	37,560	58,940	30.0	53.9

It is certainly excellent work even for an old established steel works to make basic open-hearth steel of such quality that in 245 heats practically 74 per cent contained a maximum amount of sulphur of 0.030 per cent and 86 per cent a maximum of 0.030 per cent of phosphorus. These results have been reached in Birmingham by the first open-

hearth furnaces on regular run, and have been extended over nearly six months.—*American Manufacturer.*

CAISSON DISEASE AND ITS PREVENTION

Since the pneumatic process has been in use for sub-aqueous workings, the injurious effect of high air pressures on the human system, known as caisson disease, has been made the subject of much study, with the result that means have been found for decreasing this danger to men working in compressed air.

Although it has always been recommended that considerable time should be taken in relieving the pressure when coming out of the compressed air, it remained for M. Hersent to show the great importance of coming out very slowly from high air pressures, by determining experimentally that a man may be subjected to pressures up to 76.8 pounds per square inch without injury, if sufficient time is afterward taken in relieving the pressure. Three hours and three minutes were allowed by M. Hersent in reducing the pressure from 76.8 pounds to zero.

In these experiments the maximum pressure of each test was maintained for the uniform period of one hour. Had a series of tests also been made, to determine the effect of increasing the time for maintaining the full pressure, it might have been ascertained how far the pressure itself enters in causing caisson disease, aside from the effect resulting from the relieving of the pressure. As yet there is nothing to prove that a man may not remain an indefinite time in the compressed air, if corresponding precautions are taken in returning to natural conditions. In the rules for working in compressed air, which were presented to the late International Congress on Internal Navigation, it is stated that there is no necessity for limiting the time spent in the working chamber, provided the pressure is not excessive. In pressures that have come in the writer's own experience, while at the Hudson Tunnel, and while in charge of operations at the East River Gas Tunnel, there were several indications to show that the dangerous conditions are only met when coming out of the air pressure. A man was never overcome in any way while entering the air pressure through the air-lock, nor while at work in the compressed-air chamber. In the Hudson Tunnel some mules were kept continuously in an air pressure of 30 pounds for nearly two years, working regularly without any apparent ill effects. When that work was shut down, those brought too quickly out of the pressure, died; the others, as more care was taken in bringing them through the air-lock, suffered no ill effects from their long exposure to compressed air.

On works where the pneumatic process is employed, rarely if ever is more time taken by the men in coming out of the compressed air than three minutes per atmosphere of pressure; the danger is avoided when the pressure is increased, by decreasing the number of working hours. At an hydraulic head of 100 feet, two shifts of 40 minutes each, now constitute a day's work. The unwillingness of the men to take more time in coming out of the air pressure is largely due to the disagreeable conditions experienced in the air-lock. By the relieving of the pressure a thick freezing fog is formed, and with no means provided for heating and ventilating the air-lock, a man is glad enough to escape from its icy grasp as quickly as possible.

In all heavy compressed air work, with our present knowledge, it should be insisted on, first, that sufficient time be taken in coming out of the pressure, and, second, the lock should be made so comfortable that the men would have no reason to insist on being quickly released. To compel the first, the relieving of the pressure should be mechanically regulated. As to the second, with a small compressor installed on top, supplying hot dry air to the air-lock, by proper arrangement the cold foggy conditions due to expansion of air could be entirely removed.

The writer believes that caisson disease results from an excess of carbonic acid gas accumulated in the blood while in the air pressure, which is released from solution on coming out of the compressed air, and that the gas effects the disastrous results by interfering in a purely mechanical way with the natural action of the blood in the tissues.

In normal conditions the blood holds in solution some of the carbonic acid gas formed in the process of breathing; but under an increased air pressure the capacity of the blood to dissolve this gas is increased in direct proportion. When, therefore, a man enters the compressed air, the amount of carbonic acid gas held by the blood will gradually increase

until the point of saturation corresponding to the pressure is reached. No evil effects result from this excess of carbonic acid gas in the blood as long as one remains in the compressed air, but on coming out from high pressure unless a long time is taken in the air-lock, it is impossible for the blood to rid itself through the lungs of this excess of gas as quickly as the pressure is reduced, and consequently an effervescence takes place in the blood. The gas so released by obstructing the action of the blood may be responsible for the serious consequences known as caisson disease.—*Walton I. Aims in Engineering News.*

RIVETING BY ELECTRICITY.*

For the last two years I have been experimenting on electric riveting machines, and have finally succeeded in bringing out a type of riveting machine quite capable of superseding the two systems already existing, viz., hydraulic and pneumatic riveting. There are a good many firms in this country who have to decide which system of riveting they intend to adopt for the future, in order to keep pace with the rapidly increasing competition of other firms at home and abroad, and this is the reason that I propose to read a paper on this subject at the present meeting; especially as I have seen that some firms on the other side of the Atlantic are making great efforts to introduce the pneumatic system, and promise gigantic profits to those who decide to adopt it. The machine I am describing has closed for weeks and weeks 1,200 rivets in a day of ten hours' duration, requiring the attendance of only three men and a boy.

The electric riveting machines which have up to the present been built can be carried about easily to any place in the yard, but are not made for being suspended from a crane. To the large jaw are attached two platforms at right angles, so that the riveter may be used horizontally or vertically. The system is so very simple that I need not occupy much of your time in describing it. One heavy disk is always rotating by electricity, whether the riveter is closing rivets or not. This disk can become, at the same time, an electro-magnetic coupling, so that when the current is passing this coupling a second disk, keyed on to a screw spindle, may be at once firmly attached to the revolving disk, thus the friction of the screw spindle can be regulated according to the operator's wish. The screw spindle moves a large nut at the end of the knuckle joint, which raises and lowers the die for making the rivet head. Between the two already-mentioned disks a conical friction roller can be inserted. By pressing in this roller, the motion of the screw spindle can be reversed, and the nut of the knuckle joint returned to its original position in order to be ready for a new stroke.

The pressure on the die must be regulated in proportion to the diameter of the rivet, and this is done by producing more or less friction between the two disks, which difference in friction is obtained by more or less current being admitted to the electro-magnetic coupling.

The type of the riveting machine which we are building now is made chiefly for shipbuilding purposes, and closes rivets up to 1⅜ inch in diameter; the output is, as already stated, 120 rivets per hour. When so many hot rivets are required in a short time, the question of heating the rivets becomes very important. When we started to rivet by electricity, we could not produce the number of hot rivets required by using a reasonable number of portable forges. For this reason we have made a small fan, driven by an electric motor, to supply air to a number of small furnaces, which considerably reduces the number of boys required for heating rivets.

*From a paper by F. Von Kodolitsch, read before the Institution of Naval Architects, England.

EDITORIAL OPINION.

ANNOUNCEMENT—The proposition to have the year 1899 mark the beginning of an epoch, to those engaged in the design, manufacture, and maintenance of bridges and framed structures, will, it is hoped, meet with the approval of the many engaged in this class of work and with such a wide-spread support as to insure the immediate success of this new enterprise.

The great number of engineers, architects, superintendents and manufacturers directly engaged in this branch of engineering, as well as of those in allied lines of work and manufacture, has created a demand for a monthly magazine to represent their interests.

"BRIDGES AND FRAMED STRUCTURES" will in no sense be a news-gatherer, but the aim will be to advance the knowledge of this department of engineering by high-class articles on subjects of particular interest, by writers of recognized ability.

The articles will discuss the calculation, design and construction of bridges of steel, stone, concrete, brick, and timber. These articles will be of a theoretical, technical and practical character for the bridge engineer; of a technical and practical character for the manager, taking up shop management, methods of shop work, financial means and methods, and construction; of a theoretical, technical and practical character for the architect having to do with the design and construction of fire-proof buildings, and of a technical and practical character for the railroad engineer and bridge superintendent having charge of the construction and maintenance of bridges and framed structures.

The work of the inspector of the materials of engineering will be discussed in articles on manufacture, testing and analysis.

The architecture of bridges will be treated in historical articles, while the work of the past will also be described in interesting biographies of the men who have won renown in the several departments.

The subject of foundations will be carefully represented by elaborate articles on the materials used, stone, concrete, and steel; on the methods of construction employed, and on the design and arrangement of piers, abutments, and other foundations.

The success desired can only be obtained by the coöperation of those in positions of responsibility, who will aid us in making known the character and aims of this publication.

Will you have the kindness to ask your friends, fellow-workers and assistants to give their support, and then give us the names and addresses of those who will likely become subscribers?

THE LINE OF RESPECTABILITY is being very sharply drawn among bridge manufacturers. Old-fashioned methods of construction, loose morals as to quality of work, as well as disgracefully light structures, are under the ban, and some firms who in the past were in the habit of winking at such things are very much averse to them now, and look with high disdain upon some of the lesser lights who still tolerate them.

A story went the rounds some years ago of the president of a bridge company, who, on being told of a structure built by them a score of years before, which did not have sufficient strength to support its own weight with safety, remarked, with pride: "It doesn't take much of an engineer to build a bridge with an unlimited amount of metal, but to build one to last, with very little metal, requires genius."

While there was much of truth in his remark, this particular kind of genius is happily finding a lessening field for its exercise, and while the manufacturer endeavors to build economical structures, there is not the antagonism that formerly existed to having structures "up to the specifications."

This has resulted in a growth of coöperation between the manufacturer and the consulting enginee· ··ho is now gladly welcomed

by the contractor, especially where he is so intelligent as to exercise a wise discrimination, which works to the advantage of his client, and to that of the shop-owner in like measure. He is able to waive clauses in a specification which do not benefit the structure, and which would work to the injury of the manufacturer.

The manufacturer's compliance, on the other hand, with all the reasonable demands made upon him, proves in many instances the means of his obtaining work without competition or in his having a preference shown him to the extent of several dollars per ton.

The great improvement in shops and equipment is due largely, of course, to the necessity for cheapening the cost of production to meet severe competition, but no little of it is due to a healthy rivalry between the various firms to have the best that is going.

Better shops and better machines are likewise a paying advertisement with intending purchasers, who are attracted by an up-to-date plant, and it occurs to them that better work is likely to be done in such a shop. The improvements in shop buildings are along the lines of more light, more room, and more convenient means of handling. The improvements in equipment are in the direction of machines to do work formerly done by hand, in the introduction of improved machines, and the installation of electric equipment for the operation of machines and hoisting apparatus.

Each addition made adds to the growing feeling of supremacy over some competitors, and likewise to the feeling of respectability. It points to a healthy condition in the business and is a cause for much congratulation.

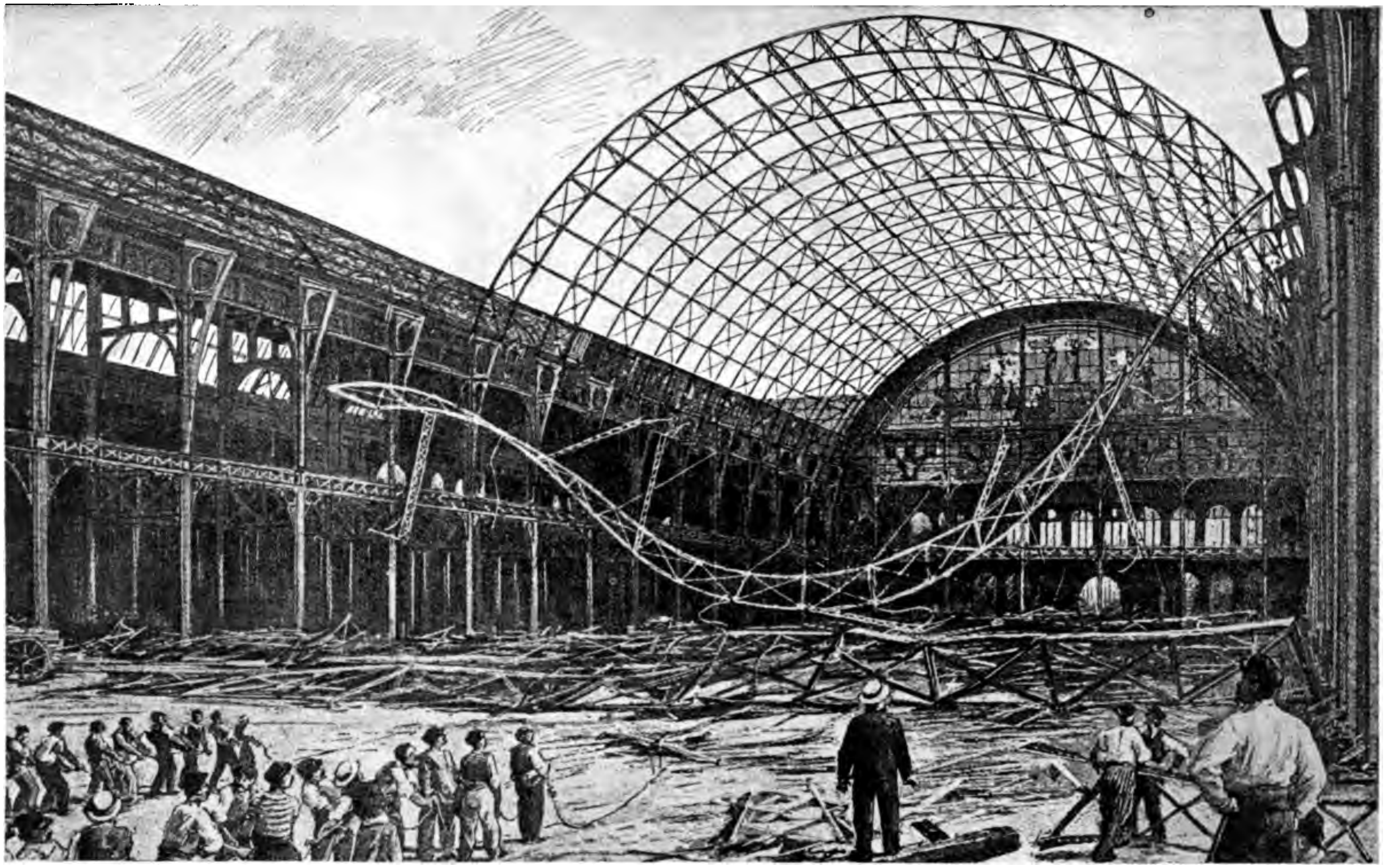
PAINTING is a word which calls up visions of a vast army of people, each one of whom is prepared to guarantee a particular brand of paint as being the long-desired article which will really act as a preservative of metal work, and, what is actually bewildering, a vast array of facts are presented to sustain the statements they have made. That there are coatings in great number answering the requirements of a first-class covering, and possessing elements of durability, but few persons will question. The bone of contention is that steel-work, carefully painted with the best covering obtainable, proceeds to rust just the same. There must be, then, some feature which is overlooked by the engineers seeking to guard against destructive oxidation. Have you ever observed the scales on newly rolled steel plates and shapes? Have you ever observed these same scales peeling off from newly erected steel-work, carrying the most expensive paints with them? Is not this the secret of so many failures, and, if such is the case, what is the remedy?

It is not far to seek. These same scales may be removed by pickling the material, as is done in the galvanizing process, before the metal is dipped in the molten coating. The question of expense comes up as perhaps a prohibition of this, in the case of the larger pieces entering into the construction of bridges, but until some purchasers have asked for bids on this basis, it cannot be stated as a practical impossibility. At least it would be feasible to have those parts of railway bridges which are most subject to the action of corrosive gases from the locomotives, such as the top struts, laterals, portals, and, possibly, the top chords, subjected to pickling before manufacture.

Another method of arriving at the same result—the removal of the scale before applying the paint—would be to follow the lead of some English railways, notably the Manchester, Sheffield & Lincolnshire Railway. In the specifications of this road for October, 1889, it is specified that no part of a structure shall be painted before erection, except such portions as shall be inaccessible for painting afterward. After the structure is erected and the scale has disappeared, owing to the rusting process, then the metal is thoroughly cleaned and the paint applied. While this may be objected to by many engineers, owing to the distrust of allowing rust to appear, it is only what takes place in a majority of instances in any event.

With the metal free from scale, we shall then be in a position to form definite and valuable conclusions as to the quality of the coatings now obtainable, and will doubtless decide that numbers of the lead paints, carbon paints, and various other coatings, are first class.

THE PARIS EXPOSITION will be of more than ordinary interest to those engaged in bridge construction, not merely on account of the many unusual engineering structures which are being erected on or near the Exposition grounds, but the bridges of Paris will re-



THE PARIS EXPOSITION—REMOVING OLD BUILDINGS.

ceive a large share of the time one may have to spend abroad. The river Seine is crossed by so many splendid bridges that it would require the space of an article to even catalogue them. Those of especial interest will be the Pont Neuf, the first stone for which was laid by Henry III, May 21, 1578, the bridge being repaired and widened in 1775, and still further in 1821. It is not remarkable on account of the spans, the longest being only 62 feet 4 inches, but on account of its age and design. Then the remarkable bridges constructed under Perronet, that of Louis XVI, which is a splendid design, and the bridge of Neuilly, which is so elegant in detail, are worthy of careful study. The bridge of Jena, built in commemoration of Napoleon's victory, and the Auteil Viaduct, are two other stone bridges of especially elegant and well-nigh perfect design.

The bridge of Alexander III, which is now being constructed for the Exposition, will be but one of the many metal bridges to be studied with profit.

It is to be a hinged metal arch of pleasing design, and monumental in character. The construction of the foundations by means of huge metal pneumatic caissons has been studied with great care by those interested in great works of engineering. These caissons have been sunk to rock by using compressed air furnished by the Paris Compressed Air Company, pipes having been laid to connect with their mains.

A notable feature of the contractors' plant which has been used was the construction of the temporary building for engineers' offices of metal. The frame-work of steel being covered by stamped sheet metal so arranged as to form an air space in the walls, this having been found to insure a cool place in hot weather, and to be a means of keeping them warmer in cold weather.

The new Exposition buildings will have many things in their design to call for comment, new types of construction taking the place of the old. The removal of the metal frames of the old buildings to make way for the new ones has been in many cases accomplished with difficulty on account of the strength and care with which they were built.

The view, which was taken from *L'Illustration,* shows the method employed in the removal of the Palais de L'Industrie, which was constructed for the Exposition of 1865. After the trusses have been pulled down they are cut apart before being removed from the site. The workingmen to the right in the picture, engaged in cutting apart the old trusses, have unconsciously shown, by stopping work to watch the fall of a truss, that the laboring man is pretty much the same the world over—inviting the invention of machinery to take his place.

The interesting works to visit are not confined to Paris, however, as France abounds in remarkable stone and metal bridges which are of easy access from the capital, and the great steel plants and manufactories will prove very profitable fields of study for the engineer and the manufacturer.

AMERICAN VERSUS EUROPEAN METHODS OF BRIDGE DESIGN had one of its frequent airings in one of the leading English engineering journals last year, and in the latter months of 1898 it was the subject of discussion in *Indian Engineering.* A prominent American engineer, in a letter addressed to that journal, makes a comparison between the 80 feet high Assam-Bengal Railway viaduct and a similar viaduct of American design, with the conclusion that the Indian structure weighs, comparatively, 23 per cent more than the American. Much of this is shown to be due to uneconomical designing, but with the constant tendency at the present time for American engineers to reproduce European methods of bridge construction, it is not easy to believe that the continental designs are either wholly or in large part bad.

The truth of the matter is that there are locations in which each design will prove the best adapted for the requirements made upon it, and the intelligent engineer is he who can use any method without prejudice, that best meets the needs of a certain locality.

As to the question of the design of details, that is quite another thing. The American systems have been the outgrowth of a very severe competition among engineers and builders, and it has been a case of the survival of the fittest. With the Continental engineers it has been the plan to cling to the methods which have the sanction of much usage.

A parting of the ways has been reached, however, in the opening of the world's markets to world-wide competition, and we can rest assured of an impartial verdict as to

which forms are best suited for shipment to long distances and erection with unskilled help.

The recent employment by some German bridge building firms of engineers who are experienced in American methods of construction leads to grave suspicions that Europeans have an idea in advance what the verdict will be.

THE PART OF THE ENGINEER in the new policy of expansion is being thoroughly discussed in the magazines and journals. Without question, the civil engineer will be the advance agent of the capitalist, for the establishment of the great works of improvement which will follow the establishment of the authority of the United States in Cuba, Porto Rico, and the Philippines. More particularly is this true with reference to the railway civil engineer, as the possible profitable schemes for new lines of railroad will be very many and constantly on the increase as new projects are formed for commercial development.

Coincident with the construction of new railways will be a demand for the steel structures to equip them. Here, then, we have the demand for the bridge engineer, manufacturer, erector, and, later, on, the superintendent of structures on the new lines.

Perhaps the contracts for the bridges and buildings will be given to a few of the larger of our bridge building firms, but the effect of this will be very soon felt with the smaller concerns, who will find increased demand at home, consequent upon the withdrawal of these firms from local competition.

Large contracts have been placed in this country during the past few years for bridge work for shipment to foreign countries, and established agencies in numbers of large foreign cities have engaged in competition and gained that experience and knowledge which will enable them to be successful in securing the award of desirable work.

Mr. Andrew Carnegie recently made the statement, in a public speech, that American steel and steel manufacturers could compete successfully in any market of the world—excepting only Pittsburg product with reference to Colorado. The great improvements constantly being effected in German mills and their growing aggressiveness in commercial affairs will necessitate constant watchfulness to enable us to retain an established supremacy. The time is distant, however, when we need have fears of a calamity from such a cause.

The establishment of a great steel plant at Ensley, Alabama, together with promise of the early construction of the Nicaragua Canal, points to a great future for our steel industries and a long continuance of the leading position we have gained.

With all this encouragement from the manufacturing side of the question, we must not forget the position occupied by the American bridge engineer among the world's engineers. In a recent communication from a leading Australian engineer, he stated that in his opinion American bridge engineers occupied the front rank as scientific and economical designers. The proof of this is found in the fact of the acceptance of American designs in such international competitions where the decisions have been unprejudiced, and no less in the comparison of the designs of our great bridges with those of foreign design. Compare the design of the Memphis cantilever with that of the Sukkur bridge over the Indus—the one a structure which was finished in pieces at the works, shipped to the site and erected without error; the other requiring to be erected at the works before shipment, to insure its successful erection in the field.

The supervising engineer will also find an increased demand for his services in the inspection of material at the mills and shops before its exportation. The careful inspection of plates and shapes at the mills insures the use of only first-class material in the manufacture of structures, while by the inspection of the finished pieces at the bridge shops, good workmanship is insured and the avoidance of occasional errors which would cause trouble in erection, and costly as well as troublesome delay.

The employment of bridge engineers on the railway systems which must eventually be formed in our new possessions is too remote to be discussed at this time, but eventually the demand will come. It behooves us, then, to be on the alert to profit by every opportunity that offers, both at home and abroad.

THE STEEL FREIGHT CAR has come to stay. The general managers of the old-time car

companies are, many of them, awaiting the time when the railways shall be through experimenting and return to wooden cars. This, to one who has seen the application of steel to so many new uses, would seem a hopeless waiting, especially when the rapid depletion of our forests is considered.

Flat cars of steel or iron were in use in this country years ago for the transportation of very heavy loads, such as cannon, coils of wire rope, and the like, but then they were not numerous enough to awaken much antagonism, and scarcely anyone thought to predict their failure.

It would be far wiser for the detractors of the metal car to save the time and money devoted to fighting its introduction and devote themselves to the conversion of their plants so as to build steel rolling stock, or else seek for other investments for their capital.

The arguments they advance as to the uselessness of steel cars after being in a wreck, of the tendency of ore to freeze fast to the bottom of the hopper cars, and all such which have a show of truth, will be met and answered by greater advantages which are offered by the use of metal instead of wood in car construction. The most important advantage being the great reduction in dead weight of train load.

The question we have to discuss is that of design. The metal *flat* car was the first to be built, and was also the best designed, in many respects, being constructed more in harmony with its functions as a bridge structure than many of the later car designs. This was done because of the *very* great weight of the loads which they were to carry, and the old-fashioned cut-and-try methods would not answer the purpose, so the bridge departments were called upon to make the calculations. Of the metal gondola cars, hopper-bottom gondolas, box cars, and flat cars recently built, there have been a number of designs which were carefully worked out by the application of the principles of bridge construction, the unit stresses of the bridge specification being somewhat modified, but advantage taken of the scientific requirements of first-class specifications.

Almost every detail in use on wooden cars has been the result of continued experimenting—one thing would be tried, found wanting in some respect, would be rejected, and something else substituted, until an arrangement was found which would answer the purpose. Many details thus fixed upon have been but poorly adapted to the demands of traffic, and quite unscientific. We venture the assertion that it will be but a few years until the old diamond truck of bar iron will give place entirely to those of girder construction, and car users will look back with wonder that the old trucks answered the purpose for so long.

The designing of a car should, then, be gone about in a logical manner, by first determining the loads to be carried both as to weight, bulk, and distribution; second, by making as simple an arrangement of the sides, ends, sills, transoms, bolsters, and trucks as possible, and calculating the maximum and minimum stresses to which they will be subjected; third, by using such a specification as Thacher's for railway bridges for unit stresses, which employs the Lannhardt Formulas—the stresses in cars are more similar to those of the Weyraucht experiments than even those of bridges—and fix upon the sections; fourth, by the detailing of the car or structure in accordance with definite unit stresses for rivets and the like; and, fifth, by taking advantage of the experience in car construction which would suggest modifications of the usual methods of bridge design.

To accomplish this and to avoid the disheartening failures which must come by car manufacturers trying to design metal cars by guess, the railway manager should see to that his car department and bridge department work together in preparing a specification analogous to that for bridges, which shall be complied with by the bidders upon steel rolling stock. This need in no way be the occasion for any conflict between these departments of railway management, but should work to the advantage of both in advancing the standing of one and extending the usefulness of the other.

THE ARTICLES OF THE MONTH touch upon some matters of great interest to the class of readers who will, we feel sure, become permanent subscribers to this magazine. The biographical sketch of Sir John Fowler will be valuable for preservation as an important chapter in the history of bridge building, not merely on account of his connection with the Forth bridge, but as illustrating the importance of a good solid experience in civil

engineering work in general as a basis for excellence in bridge engineering. The chance for the young engineer for gaining such general experience is not so good now as it was when Sir John began his career, nor as it was some years ago, for the engineering student must usually commence his specializing early in his career, but it will be well for him to get all he can and hold fast to what he gets.

The article on "Draw-Span Stresses" by Prof. Malverd A. Howe, will receive careful study, we are sure, on account of the acknowledged position occupied by him as an authoritative writer on subjects having especial reference to bridge-work, and on account of the question about the advisability of building *swing* spans having never been satisfactorily settled. Professor Howe has written a work on the continuous girder, which class of construction has been used for many swing spans, and has written extensively on drawbridges heretofore, besides having made experiments on the agreement between the theory and practice as regards such bridges. The article is an exceptionally lucid presentation of drawbridge calculations.

The foundations for ordinary bridges will require more careful attention in the future than in the past, owing to the floods becoming so much more destructive as the trees become scarcer on the hills, and owing to the greater inconvenience occasioned by washouts in a thickly settled country, than with the sparsely settled conditions of only a few decades ago. The article by Mr. A. W. Jones, C. E., on "Pneumatic Caissons for Ordinary Foundations," places on record a case where an ordinary foundation was satisfactory years ago, but with more flood water, recourse was had to a method which would place the foundation over forty feet below low water on bed rock. The fact of the cheapness of the method will cause many to consider using it, we have no doubt, and the details given will make the pneumatic process more familiar to engineers generally. When the depth of the foundation will be less than twenty feet below low water, we believe, however, that the cofferdam process will be much cheaper, and in many respects more satisfactory.

The notes on "Spanish Bridges" were selected on account of the very general and vital interest at the present time in Spanish engineering methods, which were also to a great extent those in vogue in the colonial possessions which will hereafter use the product of American shops—at least, such is our hope.

The methods by which such an *enormous* amount of calculation is accomplished every day in the year by the estimating departments of the large bridge companies are talked about by Mr. E. M. Scofield, Asso. M. Am. Soc. C. E., in a very entertaining and instructive article on "The Bridge Works' Estimating Department." The attention drawn to the necessity of a rigorous system as the means of accomplishing a large amount of work in a short time and in an accurate manner is applicable to many other departments of engineering work. The aid which calculating machines render is shown to be not only an immediate saving on the work in hand, but a saving on later work by keeping the calculator in a less worn-out condition.

Steel specifications, many of them, specify both the physical and the chemical properties of the finished product. Those most frequently used do not attempt to specify more than the physical properties, with usually a limit to the phosphorus content and occasionally sulphur as well. Mr. W. R. Webster's paper on the Relations Between the Chemical Constitution and Physical Character of Steel, which was read before the American Institute of Mining Engineers, is a comprehensive account of the study that has been given to the subject and the practical rules which have resulted. No one can read the paper without being convinced that the metallurgist should be allowed plenty of latitude in the proportions of the various elements in order to produce a steel having desired physical characteristics, and that there is good reason for many prominent writers of specifications omitting all mention as to the chemical constitution.

The "Architecture of Bridges" is written about in an introductory manner, by discussing the architectural features of some of the more pretentious bridge structures, thus opening up the way for presenting the more important features of artistic design in future numbers of this magazine.

The scarcity of literature on the very important matter of surveys for large bridges and viaducts makes the reprinting of the article by Mr. E. I. Cantine a feature of this number which will be appreciated by engineers to whom such work is assigned.

Reviews and Reports.

[This department will be open to reviews of technical books pertaining to Bridges and Framed Structures as well as to reviews of the publications and reports of technical societies and schools. We shall be pleased to receive early reports of technical society meetings and abstracts of papers of especial interest to our readers.]

The Journal of the Association of Engineering Societies for January, 1899, contains a memorial and portrait of Colonel Henry Flad, late member and president of the Engineers' Club of St. Louis, and papers on "Cement Briquettes," by Professor Jerome Sondericker, of the Boston Society of Civil Engineers; on "Power and Equipment of Electric Railways," by Messrs. H. H. Hunt and C. K. Stearns, of the same society; and a description of an "Electric Railway from Butte to Centreville, Montana," by Mr. Francis W. Blackford, of the Montana Society of Engineers. All of these papers are illustrated.

A list of the members of the associated societies, containing about 1,500 names, is published.

The report of the secretary of the association shows a remarkable degree of prosperity. Ever since 1894 the financial condition of the association has been rapidly improving, the excess of assets over liabilities increasing largely, while the annual assessments upon the societies have steadily decreased. In 1898 the annual assessment per member had been reduced to $2, and yet, at the end of the year, the assets exceeded the liabilities by nearly $3,000, We learn from the secretary that the $2 annual assessment for 1899 will probably be reduced by a dividend of $1 per member on account of surplus in the treasury.

In return for the annual assessment, the members of the societies receive the papers and proceedings, not only of their own societies, but of all the others in the association.

In view of these advantages, it is not strange that the association is rapidly increasing its importance and influence by the accession of new societies. During 1897 the Detroit Engineering Society, and in 1898 the Engineers' Club of Western New York, the Louisiana Engineering Society, and the Engineers' Club of Cincinnati became members of the association.

As the secretary remarks: "Each new society admitted to the association contributes not only to its financial strength, but also to the value of the Journal, and thus increases the inducement of outstanding societies to become members of the association.

THE ROSE TECHNIC for December, 1898, is a particularly valuable number. The "History of the Stone Arch," by Professor M. A. Howe, who is in charge of the civil engineering department of the Institute, is the leading article. The definition of the word "arch" is first discussed, different authorities being cited, then the origin of the arch is discussed, with illustrations of the various early examples of both true and false arches. The first known uses of the arch for bridges by the Romans is discussed, the construction of the enormous arched aqueducts about Rome, and in the countries subject to Roman rule, and also of Roman stone bridges in these same countries. A brief history is given of the organization known as the Brothers of the Bridge, together with some account of the work performed by them. The remainder of the article is devoted to brief descriptions of important bridges of stone in chronological order. The article is an important contribution to the historical department of bridge engineering.

The "Microstructure of Iron and Steel" is the title of a paper by J. J. Kessler, Jr. He begins by saying: "The more thorough and complete the knowledge of the physics and chemistry of any metal or alloy, from the first raw material to the last finished product, the

greater will be its value as a material of engineering, and the less will be its cost of production." The effect of a small percentage of a foreign element which might be present in a metal is traced in a brief way, and the effect of the crystalline form upon the character of the metal discussed, with reference to Howe's metallurgy of steel and other authorities to sustain the position taken, and the use of the nomenclature with mineralogical suffixes. The paper then gives a description o. Ferrite, with an account of its forms of occurrence, as well as of Cementite, Pearlyte, and Martensite.

The Rose Technic is published at the Rose Polytechnic Institute, Terre Haute, Ind.

GENERAL SPECIFICATIONS FOR STEEL ROOFS AND BUILDINGS, by Charles Evan Fowler, M. Am. Soc. C. E., Fourth Revised Edition, with tables and index. 16 pages and cover. The Engineering News Publishing Co., St. Paul Building, New York. Price, 25 cents.

The fourth edition of this specification, which has become a standard for use in practice, and which is in use in a number of universities for class work, has the same general features as the last edition. The requirements are given of a general description, the loads are specified closely—the snow load being given for various pitched roofs in five different subdivisions of the United States; formulas are given for arriving at the weight of the trusses themselves. The unit strains provide for no iron except in bars, all the main members being of soft medium steel. Requirements for corrugated iron are given, limits being placed upon the span of the different gages. Ventilators, louvres, and lighting receive attention. The details of construction are fully specified, workmanship is given space enough to insure good work, and quality of material is well defined. Painting and erection are given in accordance with the best modern practice.

The tables are of great value, fifteen different sets of coefficients are given for Pratt trusses, and twelve sets for Fink and Fan trusses, together with the general formulas from which they are deduced. By their use in connection with a slide rule, all the ordinary forms of trusses can be worked out without recourse to graphics. Tables are given for steel column unit strains and for shearing and bearing values of rivets. A plate is given which shows all the ordinary details of attaching corrugated iron covering. An index is provided which makes it easy to refer quickly to any clause of the specification.

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BRIDGES

AND FRAMED STRUCTURES

AN ILLUSTRATED MONTHLY MAGAZINE

FOR
ENGINEERS
ARCHITECTS
INSPECTORS
SUPERINTENDENTS
MANUFACTURERS

VIADUCTS
BUILDINGS
MASONRY

LEADING FEATURES OF THIS NUMBER

THE D·H·RANCK·PUB·CO· CHICAGO·

Contents for May, 1899.

*Illustrated.

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VOL. I. Bridges and Framed Structures. NO. 2.

AUTHORS AND THEIR ARTICLES IN THIS NUMBER.

FRANK C. OSBORN.—Graduated at Rensselaer Polytechnic Institute, Troy, N. Y., in the year 1880. Accepted at once position of assistant engineer to Louisville Bridge and Iron Co., Louisville, Ky. In a few months was made principal assistant engineer, and held the position until March, 1885. Resigned to accepted similar position with the Keystone Bridge Co., Pittsburgh, Pa. Held this position until 1887. Entered firm of G. W. G. Ferris & Co., inspectors of steel construction. Retired from the firm in 1889, and took position as special assistant engineer to Mr. Max S. Becker, chief engineer of Ohio Connecting Railway, then building a bridge across the Ohio river at Pittsburgh. From this position to King Bridge Co., serving as chief engineer for three years. Since 1892 in independent practice as designer and inspector of steel construction, doing business under the name The Osborn Co., civil engineers. Member of The American Society of Civil Engineers, also of The Institution of Civil Engineers. Was president of The Civil Engineers' Club of Cleveland. Has published general specifications for highway bridges, for railway bridges, and for bridge substructures. Also a hand-book for engineers, "Tables of Moments of Inertia and Squares of Radii of Gyration."

ALFRED D. OTTEWELL—The author's first introduction to bridge work was obtained in the early seventies, when he spent several years in the drawing office of A. Handyside & Co., of Derby, England. Obtaining one of the late Sir Joseph Whitworth's scholarships he was enabled to improve his practical training in the workshops of Sir Joseph Whitworth and Co., Manchester, and his theoretical knowledge at Owen's College, now Victoria University. In 1882 he crossed the Atlantic and studied American practice at the Pittsburgh Bridge Co., the Edge Moor Iron Co., and at the Michigan University under Professor Greene. He then located on the Pacific Coast and practiced, first as engineer of the California Bridge Co., and afterwards as consulting engineer until 1894 when, owing to the death of his father, it became necessary to return to his native town where he now is.

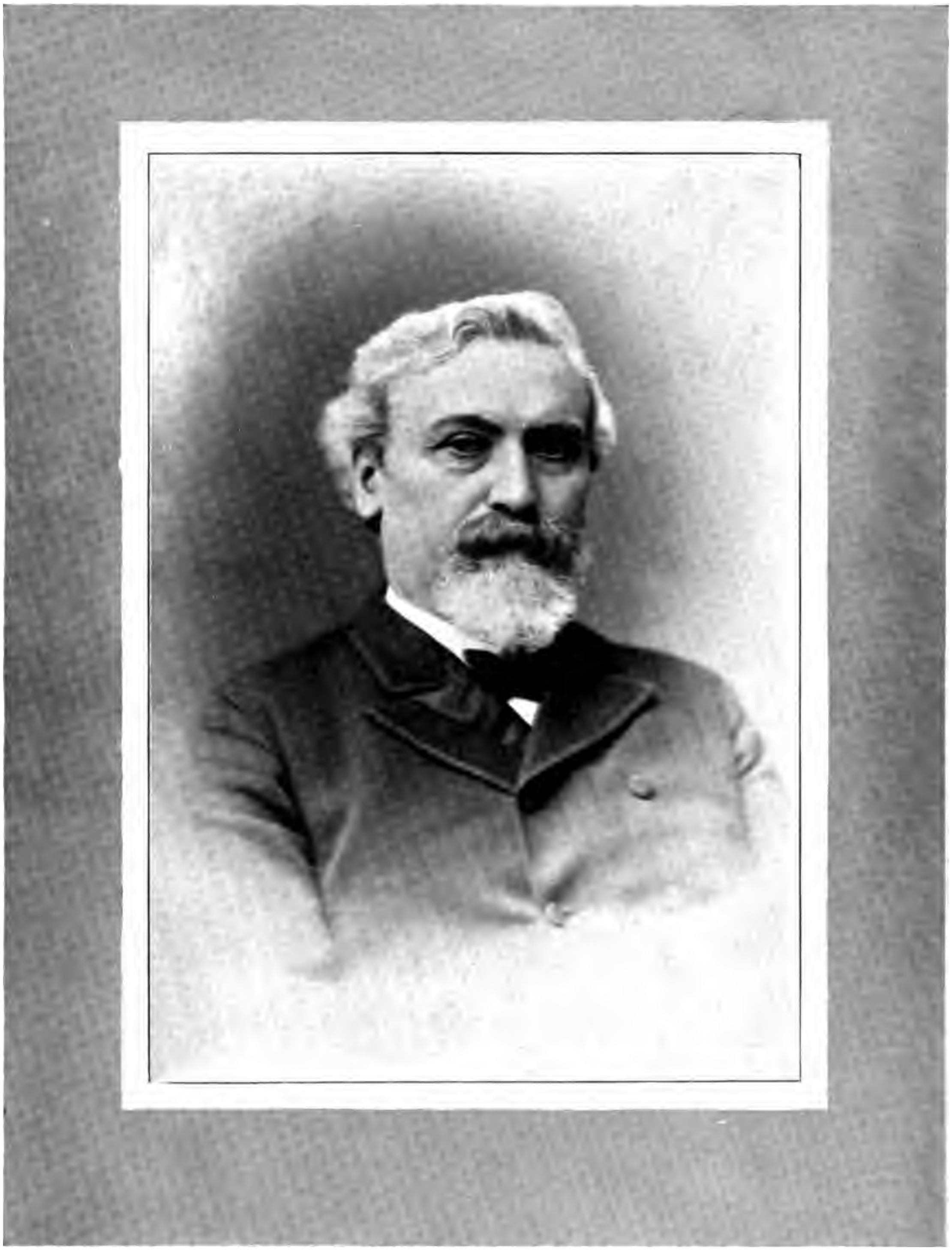
His principal work can be seen in the Sutro Baths, San Francisco, Cal., the Roseburg Cantilever Bridge, Oregon; the Downey Ave. and First St. Bridges, Los Angeles, Cal., and other bridges and buildings on the Pacific Coast.

In 1887 he contributed to Engineering News a series of articles on "The New Method of Dimensioning," "Economy in Bridging Rivers," etc., and among his other literary contributions are a paper on "Combination Bridge Building on the Pacific Coast," Trans. Am. Soc. C. E., October, 1892; and a discussion on "American vs. English Railway Bridges," published in The Engineer in 1897.

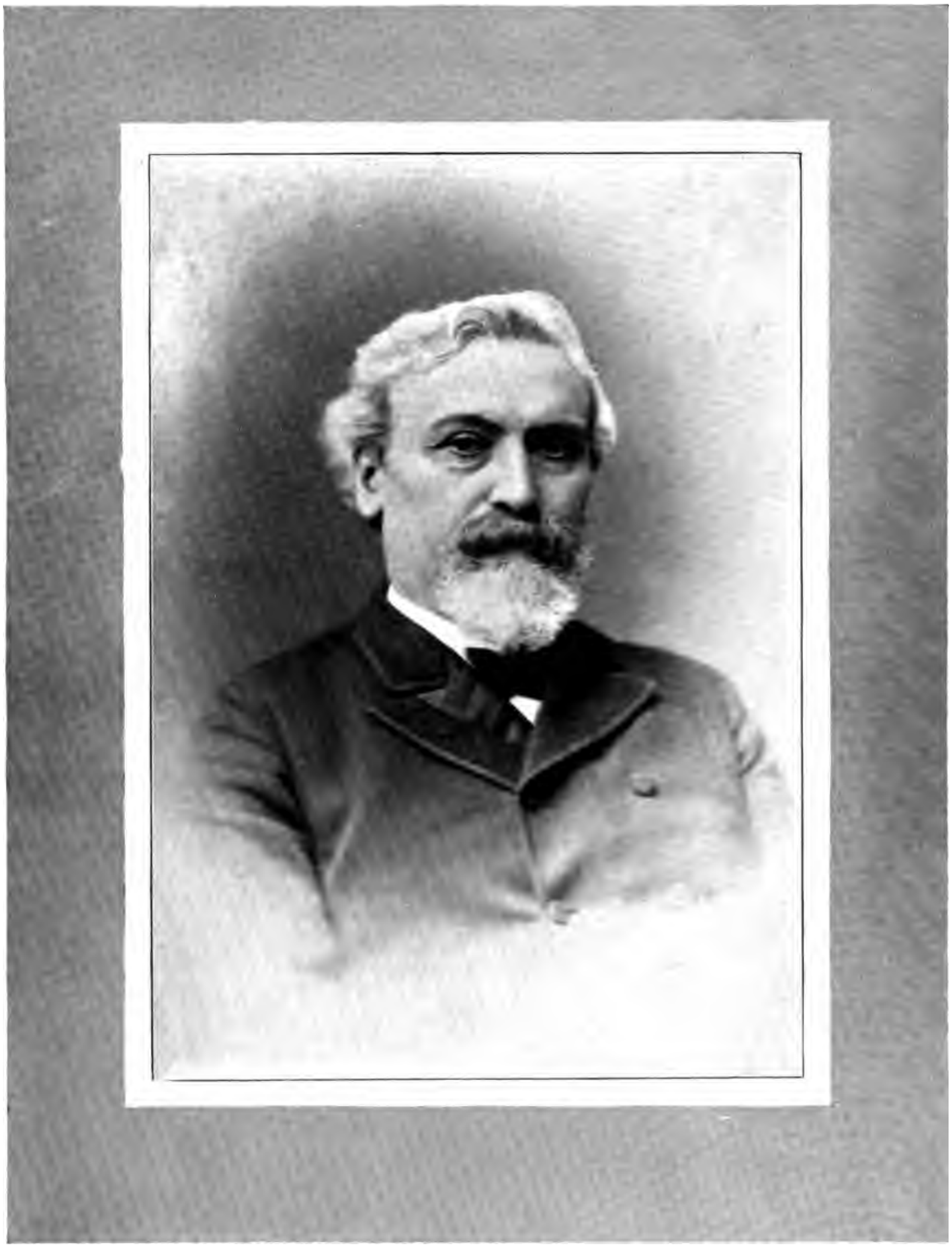
CHARLES EVAN FOWLER.—Born in Washington County, O.; after completing common school work at Marietta, served with large business house in Portsmouth, O.; took course in railroad and bridge engineering at Ohio State University; after employment as instrument man on preliminary railroad surveys became bridge engineer of the Hocking Valley Railway; was employed with large bridge concerns as designer, and by The Indiana Bridge Co. as engineer of construction; spent two years in Southern California on combination bridge work and on irrigation engineering; accepted position as estimator for Youngstown Bridge Co. in 1892 and six months later was promoted to chief engineer, which position he held for over six years. During this time the Knoxville arched cantilever, the Market St. plate girder arch at Youngstown, and numerous large railway and municipal bridges, were constructed under his direction.

Engaged at present in private practice, member firm of Foyè & Fowler, New York City. Is a member of American Soc. C. E., author of "The Cofferdam Process for Piers," "General Specifications for Steel Roofs and Buildings," "Engineering Studies," and numerous technical articles in Engineering News, Stone, and the Engineering Magazine.

WILLIAM R. WEBSTER—Biographical notice appeared in April number of BRIDGES.



ALBERT FINK.



ALBERT FINK.

Bridges and Framed Structures.

VOLUME I. MAY, 1899. NUMBER 2.

THE INSPECTION OF IRON AND STEEL

ITS DEVELOPMENT, WHAT IT IS, AND ITS ADVANTAGES

"Eternal vigilance is the price of safety."

HOW generally the motto applies! No one can entirely free himself of all blame, if he has carelessly accepted and paid for an article, a service, or a piece of money without taking the precaution to see that he has received what he paid for. cellar to garret to see if it is substantially built, if the drain- The careful man, in buying a house, first examines it from age system is tight, if the various classes of work performed thereon have been honestly done. If he feels himself out of his element in such an examination, he gets some friend, or employs some expert who is versed in such matters, to make the examination for him. If a man buys a horse, he is seldom satisfied to take the jockey's word for its good qualities; if disappointment followed such confidence, he could hardly feel himself entirely blameless.

So it is when a man, or a corporation, buys a bridge, a building, or any structure containing iron or steel. The careful man, or corporation takes all precautions to see that every detail is constructed just as it should be and that the material is of the quality he desires and pays for.

But in the case of iron or steel structures no cursory examination can truly determine whether the material and workmanship is all as it should be. No scrutiny, however minute, of a finished piece of iron or steel can discover whether or not it is free from imperfections in its composition, and from abuse, in the treatment it has received during the various processes in the manufacture of the finished parts of the structure that may seriously and even fatally affect its strength. To be sure that he is getting what he is paying for, the buyer must have means of knowing that the raw materials are of good quality, that the metal, when rolled, contains no harmful ingredients in dangerous quantity, that the material is properly handled, straightened, and finished, that the various processes incident to its manufacture into bridge or other structural parts are all properly and conscientiously done, that the parts when finished are all of proper size, that they are painted and treated as they should be; in short, he must, either himself or by a representative working in his interest, follow the progress of the material from the ore to the finished structure. Then, and then only, can he be reasonably positive that his structure is what he desires and pays for.

Such careful attention to details requires that some one be at mills at

all times when material is being rolled for the work in hand to conduct the tests of all the material produced, and to measure and carefully examine the bars as they are finished. It requires that some one be at the shops during the manufacture of the parts of the proposed structure from the material received from the mills, to see that all the details of the treatment it receives are in accordance with the specifications, and that the finished parts all comply with the requirements as to size and quality of workmanship.

Few purchasers can look after such things personally, they have other things to attend to. Engineers and architects in charge of structures have all they can do to superintend the other parts of the work in hand. The matter of the inspection of the materials entering into them is a detail that they must intrust to an assistant. And so men expert in this particular sort of superintendence have become useful and found their place among the arts. The inspector makes it his business to fully understand all the various processes and their results, and to look after his client's interests in all respects.

There was a time when one man could comfortably attend to such duties himself, and personally follow the progress of the material in all its various processes. The shops and mills at which iron was manufactured and where the finished parts of structures were produced were often one and the same, or if not, the processes followed each other in such rotation that one man could get from mill to shop and keep proper consecutive track of the work. But the industry has of late years grown to such enormous proportions and has extended over such a large area that it is impossible for one man to properly inspect the work in all the stages. Bridge companies now have a number of mills from which to order the material necessary for their work. They are likely to have plates from one mill, beams and channels from another, and shapes from still a third; and the mills are often great distances apart. Frequently, too, the shop is at work on some portions of a contract while the mills are still furnishing materials. It is manifestly out of the question for any one man to thoroughly inspect work at all these places at one time. He must have assistance in some way.

Men who have become expert and experienced in this sort of work have made inspection their particular business, performing this service at a compensation based on the tonnage in the work, instead of entering the service of the engineer or architect in charge at a salary. Such men, as they found it impossible to economically perform their duties personally on account of the excessive expenses of traveling about, adopted the method of reciprocating among themselves; an inspector in Pittsburg undertaking to do the mill inspection on one piece of work for another located in Philadelphia, while the latter attended to shop inspection at shops in his vicinity for the former. Naturally, from such alliances among inspectors, there has resulted the formation of inspection bureaus or companies. Such companies employ men permanently at the various mills and shops and maintain extensive general offices, at which the clerical work of copying and forwarding reports of tests, progress of work, etc., is performed. By securing large quantities of inspection work, they are able to keep good men at all the localities necessary, maintaining a perfect system of effective inspection and giving their clients regular reports of the quality of material and workmanship, progress of the work, and information as to tests, shipments, etc., which, when completed,

comprises an accurate record of the structure in question and surety that it is built as it should be.

Such a company, to be effective and to economically perform good service, requires the most careful organization among its corps of inspectors and clerks. Detailed systems for the handling of such work have been adopted by some companies as the result of much study and experience, and the inspection of various classes of work, for clients in all parts of this country and abroad, done at mills and shops in all the centers of manufacture, is performed with the machine-like regularity and uniformity which alone is the safeguard against mistakes, lost records, and careless work.

The following brief description of the methods adopted by the Osborn Company of Cleveland, Ohio, one of the principal inspection bureaus of this country, will illustrate the care taken to give all work the closest attention, to keep track of its employes, and to insure the best results to its clients.

When the contract for a bridge, or any steel or iron structure, is let, the inspecting company and the contracting bridge company are mutually notified. The former is supplied with a copy of the strain sheet and general plans and specifications. These are first examined at the inspecting company's general office, and any necessary notes made of special features, and then sent, with instruction slip A attached, to their inspector located at the contractors' shops. When the bridge company places its orders for material with the various mills, copies of these orders are sent to the inspecting bureau, where they are copied in duplicate on the blanks C, one copy of which is sent, with instruction slip B attached, to the inspectors located at the various mills where the material is to be rolled. The weights of the various items of material ordered are estimated and entered in the other copy, which is retained at headquarters for future reference.

Each mill inspector first carefully compares his copy of form C with the mill order book, to see that no changes or mistakes have been made in ordering. As fast as the steel is manufactured, test specimens are taken by the mill inspectors and the necessary tests made thereof, the report of tests on each separate blow or melt of steel being sent to headquarters, together with data from the mill chemist's certified report of chemical analysis, on the inspector's test slip D. Drillings are also taken, when required or deemed advisable, from the test pieces, and sent to headquarters, where check analyses are made to test the accuracy of the mill chemist. The test slips D are collected at the general office and copied on the test report blanks E which, after press copying, are sent to the engineer or architect. While the material is being rolled into the shapes ordered, the inspector is constantly on hand and, from time to time he calipers and measures the pieces to see that they are of the requisite size and thickness. He sees that the bars are properly straightened and cared for while cooling, and that they show no flaws or ragged edges. As fast as each bar is inspected and found satisfactory, he strikes into it a distinguishing mark of the inspecting bureau, furnished him from the general office, which signifies that the piece has satisfactorily passed his examination and is composed of material the tests of which have been satisfactory. The stamp he uses is recorded in the general office against his name, so there can never be any question as to who performed the inspection on any piece of material. He keeps his general office informed regarding the pieces he has inspected from day to day on any one

piece of work by means of the report F. As fast as the material is shipped from the mill, he forwards to the general office the tissue copies of invoices, furnished him by the mill. There the items and weights are checked against those on his report F and against the copy of form C retained at headquarters. The invoices are then copied on the blank G, which is sent to the engineer or architect after press copying.

Thus the engineer or architect in charge of the work is kept reliably informed just what material has been rolled and shipped, and he knows exactly what the results of all the tests performed on the material have been and what powers of resistance it can be expected to develop. He is protected from any fictitious claims of a delinquent bridge company of delay at the mills. The inspecting bureau has detailed records of the dates on which inspection was performed on any lot of material, and is protected against fictitious claims of delay in the inspection of material at the mill.

As soon as the material begins to arrive at the contractor's shop, the shop inspector located there begins making regular weekly reports on the work in hand to his general office. He has, in the meantime, received from the bridge company a full set of the working drawings of the structure, he has carefully checked them against the general plans received at the outset, and has called attention to and had corrected any errors in them or differences between them and the general plans furnished him as his guide. He has also made a careful estimate of the weights of the various finished parts, and a list of all the parts that will be required according to the contract.

It is his duty to be constantly on hand about the shop during the progress of the work, watching the various processes and seeing that everything is done according to the specifications that have been furnished him. He sees that only material bearing the mill inspector's stamp is used and that it has arrived from the mills in good condition. By watching the processes thus closely he is not only able to detect faulty work which would be covered up when the piece is finished, but he can often save both the bridge company and his employers considerable time and expense by noting mistakes early, while they may still be corrected at little cost. When a piece is finished, he makes careful final examination of it, comparing all dimensions with the plans, testing the riveting, etc. It is then painted under his superintendence and he stamps in the piece, in a conspicuous position, a similar distinguishing mark to that used by the mill inspector, to indicate that the shop work has all been properly done and that the piece is as it should be in every respect.

The shop inspector's weekly reports come to the general office on three forms, H, I, and J; being respectively, his report of material received from the various mills, of the work performed on the structure in the shop, and of finished pieces shipped from the shop to their destination during the week. Form H is first checked against form G, and then the three forms are press copied and sent to the engineer or architect. The method of reporting the condition of the various members of a structure, from week to week, on form I, may require more detailed explanation. The first column, headed "required," shows the number of pieces of a particular mark required. The number in this column remains constant from beginning to end, and the total of the numbers in the other columns, on the same line, always checks with this. The other columns show to what stage in the process of manufacture each piece has reached each week. Thus, in a bridge, there may be

four end posts required marked aB. The figure 4 would then appear in each report in the first column. One week there might be a 1 in the third column, a 1 in the fifth, and a 2 in the next to last, showing that one was assembled, one riveted, and two finished awaiting shipment. When the same figure appears in the last column as in the first, all the pieces of that kind have been shipped, and when all the pieces required for the work are shown in the last column, the material has all been finished and is on its way to its destination.

For every shipment of material that is made, copies of the shipping bills, giving the itemized scale weights of the material on each car, are furnished the inspector by the bridge company. He first makes a note of these items and weights, checking them against his list of parts required to complete the work, and the estimated weights he has. He then sends the bills to the general office, where they are copied on form K, which, after press copying, is sent to the engineer or architect. Reports of tests of full sized eye-bars for bridges are made out on the blank L, press copied and sent to the engineer. Form M is similarly used for reporting results of tests of cast iron.

When a job is finished, a final report is sent to the engineer or architect, stating briefly the work that has been done, noting any unusual features that have developed during the inspection of the material, or cases where material was rejected. This report includes a summarized statement of the weights of the finished parts, comparing the estimated with the actual scale weights, and also a statement of the shipments made, giving dates of shipment, car numbers, and initials and weights.

The engineer or architect then has a complete record of the material used on his work, the dates on which the shipments were made from mills to shop, complete records of its progress through the shop and of the shipments from the shop to the building site. It should be noted that all the reports and blanks used are uniformly of letter size and printed on thin paper. They are thus in the best possible shape for filing and do not make an unnecessarily bulky package. The final report embodies all the points necessary for ordinary cases of future reference. The inspecting company has not only duplicates of all these documents carefully preserved, but all the detailed information of all kinds relating to the work are carefully filed with the copies of reports, correspondence, etc., and stored safely away, thus forming an additional safeguard against loss of records. If, at any time in the future, information should be wanted concerning the work; if repairs are to be made, or any question arises as to the strength of the structure, the inspecting bureau can furnish the information, if necessary.

One other of this company's many forms may be interesting. Form N is a blank form of weekly diary, furnished to all its employes, wherever located. The employes are required to keep thereon a concise diary of their doings and movements and note the time spent and expenses chargeable on each piece of work. These are sent to the general office at the end of each week, where they are checked over and the time and expenses of each man entered against each job. The company thus has a pretty good check on each man, as to whether he is attending to his duty and spending proper time on each piece of work allotted to him, or not.

A. **SHOP MEMORANDUM**

Job No. ....

Name ....

Specifications ....

Contractor ....

Report to ....

" every ....

REMARKS ....

....

B. **MILL MEMORANDUM.**

Job No. ....

Name ....

Specifications ....

Mill ....

....

....

REMARKS ....

....

C.

No ———— *Sheet No* ————

Order No. ———— Contract No. ———— 189 ——

To ————

Contractor ————

	ITEM NO.	NO. PCS.	DESCRIPTION.	SECTION.	LENGTH. FT.	LENGTH. IN.	WEIGHT.	REMARKS.

D.

Date .... 189 .., ... Inspector.

Mill ....

Contract ....

Order No ....

Blow or Cast .... Furnace Heat ....

Ingot .... Slab .... Piece ....

Test cut from ....

Dims .... Area ....

Elas. Lim .... Per□" ....

Ult. Str .... Per□" ....

Elong in .... Per ct ....

Red. Dims ....

Red. Area .... Per ct ....

Fracture ....

Cold Bend ....

Quench Bend ....

Drift Test ....

C ...... Ph ...... Mn ...... Sul ...... Si ......

Acc. or Rej ....

Remarks ....

....

E.

Job No.________ Report No.________

Report of Tests of ________ **Manufactured by**________

For________ **Order for**________

Reported to________ 189___

ABBREVIATIONS.—Pl., Plate. Ch., Channels. L., Angle; C., Cup; A., Angular; Ir., Irregular; Gr., Granular.

Date of Test						
Blow or Melt						
Furnace Heat						
Test cut from						
Original Dimension						
Original Area						
Elas. Lim. Actual						
Elas. Lim. Lbs Per Sq. In.						
Ult. Str. Actual						
Ult. Str. Lbs Per Sq. In.						
Elongation in....inches						
Per Cent. Elongation						
Reduced Dimensions						
Reduced Area						
Per Cent. Reduction						
Character of Fracture						
Cold Bending Test						
Quench Bending Test						
Drift Test						
Carbon						
Phosphorus						
Manganese						
Sulphur						
Acc. or Rej.						
Remarks						

We certify that the above-described tests were carefully made.

THE OSBORN CO.

Tested by________ **By**________

F.

Job No.________ Report No.________

To________

The following material has been inspected at ________

on account of ________ **order for** ________

Date of inspection________

Purchaser's Order No.	Purchaser's Item No.	Mill Order No.	Heat No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH.		WEIGHT.	REMARKS.
						Feet.	Inches.		
	We certify that the above described material has been carefully inspected.								

G.

Job No. ____________

Shipping Report No. ______

Date of Shipment ______

Shipped from ____________

Shipped to ____________

Car No. ____________ Cleveland, O. ____________ 189 __

Purchaser's Order No.	Purchaser's Item No.	Mill Order No.	Sent No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH.		WEIGHT.	REMARKS.
						Feet.	Inches.		

H.

Job No. ________ Report No. ________

REPORT OF MATERIAL RECEIVED ____________ 189 __

At the shops of ____________ On ____________

____________ For ____________

DATE OF INVOICE	KIND	CARS		FROM	WEIGHT
		INITIALS	NUMBER		
				Total Weight of above	
				Previously reported	
				Total to date	

THE OSBORN CO.

By ____________

I.

Job No. ________ Report No. ________

REPORT ON CONDITION OF WORK ____________ 189 __

At the shops of ____________ On ____________

____________ For ____________

SPAN	LOCATION IN STRUCTURE	NUMBER OF PIECES									
		Required	Punched	Assembld	Reamed	Riveted	Faced	Forged	Bored	Finished	Shipped

THE OSBORN CO.

By ____________ Inspector.

L.

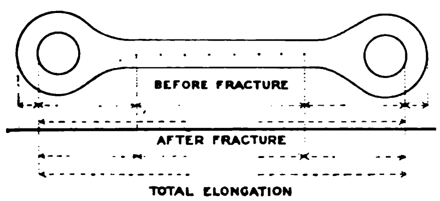
Job No................... **Report No.**..................

Report of test of.. **Manufactured by**..

From Material Rolled by.. **For**..

Reported to..

Date of Test.. Blow or Melt No..

Head A.		Head B.
Width..................Inches		Width..................Inches
Thickness..................Inches		Thickness..................Inches
Dia. pin hole.................. Inches		Dia. pin hole.................. Inches
Excess..................per cent.		Excess.................. per cent.
Elongated Diameter of pin hole A..................Inches		Elongated Diameter of pin hole B..................Inches

Elongation in.................................. ......12″ spaces

....

....

Nominal Section.................. Actual Section.................. **ACTUAL AREA**..................

Elastic Limit: Gauge.................. Actual.................. **LBS. PER SQ. IN**..................

Ult. Strength: Gauge.................. Actual.................. **LBS. PER SQ. IN**..................

Elongation; in..................inches.................. .... **PER CENT.**

Elongation: in..................feet.................. .... **PER CENT.**

Fractured Section.................. ....Area.................. **REDUCTION**.................. **PER CENT.**

Location of fracture..................from back of Eye..................

Character of fracture..

Accepted or rejected..

Remarks..

....

Specimen test from same blow o: melt shows the following results:

Elastic Lim. per sq. in.. Ult. Str. per sq. in..

Per cent. Elong. in 8 in..Per cent. Reduction..

Carbon.................. Phos.................. Mang.................. Sul..................

We certify that the above described test was carefully made.

Tested on..machine. THE OSBORN CO., Civil Engineers.

At.. By..

By..

J

Job No.______ Report No.______

REPORT OF SHIPMENTS ______ 189__

From the shops of______ On______

______ For ______

INVOICE NO.	DATE		CARS		DESCRIPTION	WEIGHT
			INITIALS	NUMBER		
					Total Weight of above	
					Previously reported	
					Total to date	

We certify that the above described material has been carefully inspected.

THE OSBORN CO.

By______Inspector.

K.

Job No.______

Shipping Report No.______

Date of Shipment______

Shipped from______

Shipped to______

Car No.______ Cleveland, O.______189__

CONTRACT NUMBER	NO PIECES	DESCRIPTION	MARK	WEIGHT	REMARKS
		We certify that the above described material has been carefully inspected.			

M

Job No.______ Report No.______

Report of Tests of Cast Iron Manufactured by ______

For______Order for______

Reported to______189__

DATE	CAST NO	SPECIFIED LOAD	SECTION	C. TO C. BEARINGS	BREAKING LOAD	DEFLECTION	CASTINGS REPRESENTED	REMARKS

We certify that the above described tests were carefully made.

THE OSBORN CO.

Tested by______ By______

N.

WEEKLY DIARY

Of

For week ending

JOB	DIARY	HRS.	EXP.	JOB	DIARY	HRS.	EXP.
SUNDAY				THURSDAY			
MONDAY				FRIDAY			
TUESDAY				SATURDAY			
WEDNESDAY							

☞ Each employe is to fill out this form, day by day, giving complete description in detail of the kind of work done, at what place and time spent. He is also to state in detail what moneys he has expended on this Company's account, and for what purpose. At the end of the week noted hereon this sheet must be turned into the office, giving a complete diary and statement of time and expense for the week.

FRANK C. OSBORN,
M. Am. Soc. C. E.

[*To be Continued in June Number.*]

RECENT ENGLISH PRACTICE IN BRIDGES AND FRAMED STRUCTURES

THE examples illustrating this article will appear differently to different readers. To an engineer in practice in the Western states, Fig. 1, for example, will appear quite unsuitable for his practice, while to an engineer in an Eastern city it may possibly appear just the bridge for a particular site under his consideration. The suitability of a bridge depends upon environment, one bridge being suitable for one situation, another for another, and the art and skill of the engineer is measured by his power of adapting his work to the conditions

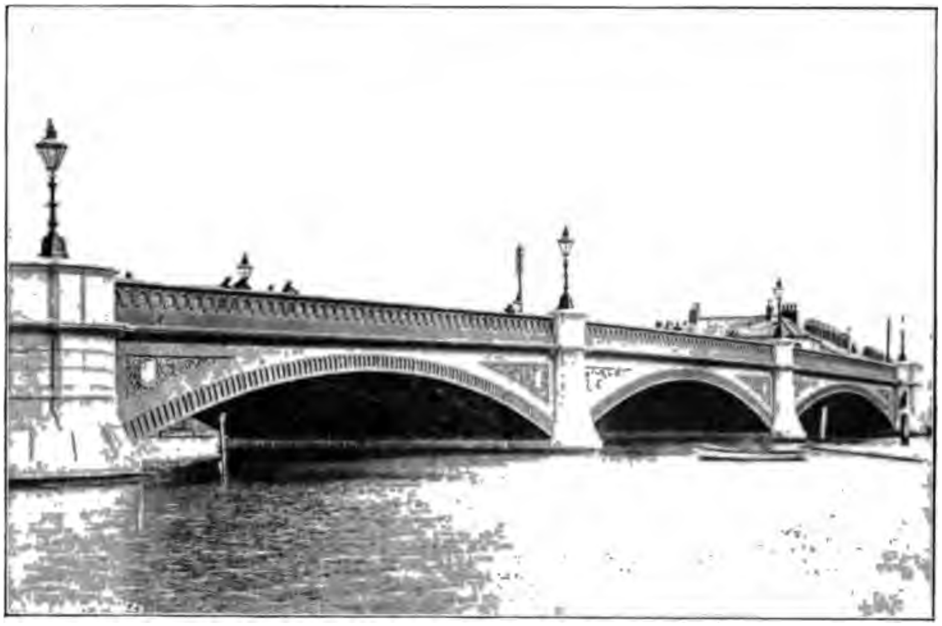


FIG. 1—ROAD BRIDGE, BELFAST.

of the situation. If, therefore, these examples appear "Quite English, you know," they are not for this reason alone worthy of either condemnation or commendation. They are only to be commended in so far as they efficiently fill the conditions of the surrounding circumstances, and only to be condemned in so far as they fail in this respect. That the work of an English engineer may be subject to either the commendation or condemnation of his American cousin is not at all surprising, since the circumstances surrounding each engineer are different.

When a corporation like Belfast can borrow at the rate of $2\frac{3}{4}$ per cent per annum, or less, all the money it needs to pay for a bridge; when iron is

FIG. 2—GOURITZ BRIDGE, CAPE COLONY.

FIG. 3—RAILWAY BRIDGE AT DUBLIN.

smelted from the ore within a few miles of the city, it cannot be surprising to find that cast iron is plentifully used in the construction of a bridge. If, however, Belfast had been a Western city of the United States, thousands of miles from an iron mine, and where money could command 4 or 5 per cent, such a bridge would be out of the question. In such a case we should expect to find, and do find, the material most available being used in the construction of a bridge; in other words, combination bridges, made mostly of timber, with a minimum of iron, the former being plentiful and the latter scarce.

We have said the work of the engineer is efficient only in so far as it fills the conditions of the surrounding circumstances. Now, to fill these conditions they must first be understood. The more varied these circum-

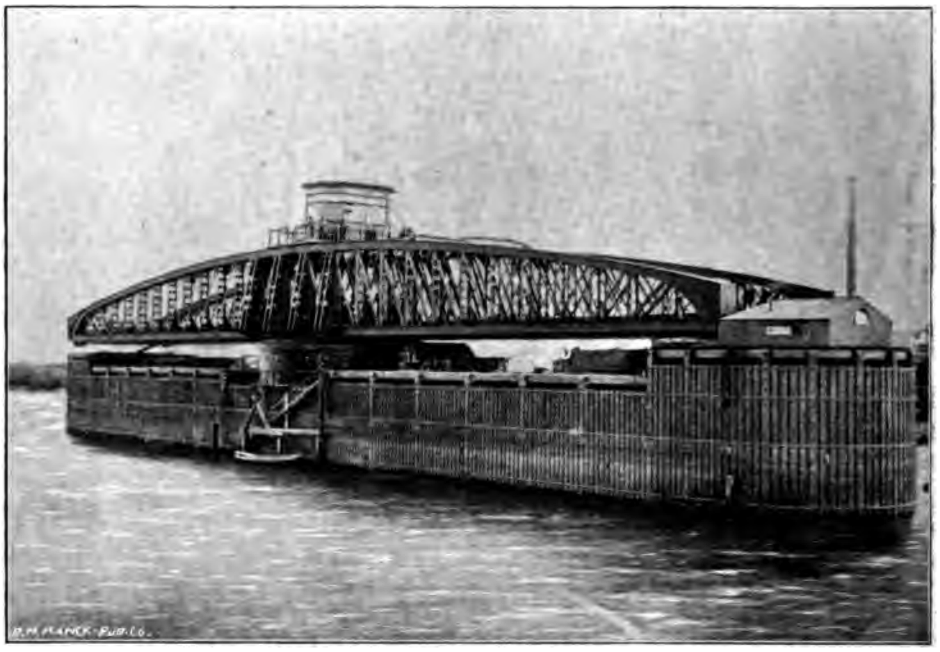


FIG. 4—SWING BRIDGE OVER OUSE.

stances the more difficult it is to understand and satisfy them. From this point of view the English engineer may reasonably expect criticisms from his American cousin, for, although England occupies a very small portion of the earth's surface, the English bridge builder covers a much larger portion, so that if an English engineer who is called upon to design, say, a bridge over the Trent this week, a bridge for India next, and one for the Soudan the week after, it is not a matter for much surprise if we find him guilty of an occasional error, and before being too severe in our criticism, we, critics, should do well to remember that he is only human, even if we are not.

If nature abhors a vacuum human nature dislikes a change, and if human nature dislikes a change it is not very difficult to believe that the ever-changing conditions in the work of the English engineer are to some extent

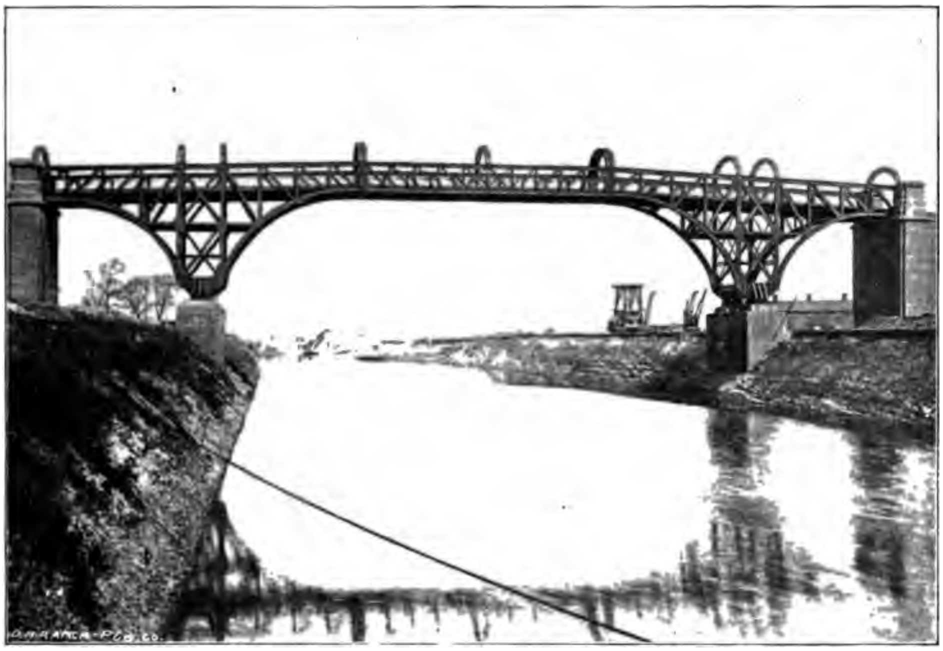


FIG. 5—ROAD BRIDGE OVER MANCHESTER SHIP CANAL.

FIG. 6—MIDLAND RAILWAY BRIDGE OVER THE TRENT.

imperfectly carried out. That these conditions are ever changing is seen from the examples illustrating this article. Take the Belfast bridge again for example. Few, if any, bridge works in the United States are ever invited to design or tender for a cast iron bridge, and therefore few have foundries of their own. In England, however, a bridge shop is always liable to be asked for such designs and tenders, and therefore most shops have foundries of their own. The absence of a foundry naturally tends to the disuse of cast iron, the presence of a foundry tends to the application of such iron. For the narrow rivers of England cast iron spans seem appropriate for highway bridges, but such material for railroad bridges has gone out of use in England, as in the United States, that is for the main members of the structure.

The foregoing remarks have been made, not by way of apology, but

FIG. 7—AQUEDUCT OVER MANCHESTER SHIP CANAL, OPEN.

by way of explanation. With an experience of twelve years in the United States the writer might be disposed to think that cast iron bridges were out of date, that the bridge shown in Fig. 2 was an examle of plagiarism, that in Fig. 3 unsightly, in Fig. 4 unnecessarily heavy, Figs. 5 and 6 unscientific, and so on; but on fuller information he is disposed to think such criticisms would not be altogether right.

If "a thing of beauty is a joy forever," then the cast iron bridge of Fig. 1 surely cannot be considered out of date.

If "imitation is the sincerest flattery," then Mr. C. C. Schneider must feel flattered when he sees the bridge in Fig. 2. If similar conditions require similar treatment, then the site of Fig. 2 certainly warranted Sir Benjamin Baker's repetition of the type of the Niagara River bridge. Advocates of single intersection may, however, regret that Sir Benjamin Baker repeated

the double intersection in the shore and river arms, since the outline so readily conforms to the adoption of the Petit truss for two or four panels on both sides of the pier, as is readily seen in Mr. J. W. MacLeod's bridge over the Kentucky River, for the Louisville Southern Railroad.

That a cast iron bridge naturally lends itself, or conforms, to ornamentation, and that a wrought iron one does not, is readily noted by the pleasure given to the eye by the cast iron bridge in Fig. 1 and the absence of pleasure in looking at the wrought iron bridge in Fig. 3. In the former case the eye delights to rest upon the structure, as there is no reminder of effort to please, and no suggestion of obligation. In the latter bridge, however, one is constantly reminded of an effort to please. One sees a rosette stuck here, a bead there, and a host of other such efforts, but the

FIG 8.—AQUEDUCT OVER MANCHESTER SHIP CANAL.

joggle, the bent stiffeners, the splice, the rivets are always in evidence, manifesting a want of homogeneity in material, and a spirit of utility in opposition to that of ornament.

Fig. 4 shows a bridge compact and trim, but looking at its span (250 feet), its weight (510 tons) cannot be considered light from an American point of view. Nor can its depth of truss be considered excessive.

The writer has often noticed in English bridges the presence of transverse top lateral arches, such as those in Figs. 5 and 6, without any diagonal system for securing rigidity from the abutment against vibratory or wind strains. So far he has been unable to secure a satisfactory explanation for the use of these arches. Why the depth of truss could not be increased a few feet to allow the use of an efficient top lateral system is more than he can say. If they are through bridges, why not have an efficient top lateral system? If they are Pony trusses, why these arches? If they are not Pony

trusses, that is if the posts are not held rigidly vertical, and the top chord in line, by the floor beams, then the top chord is either weak or wasteful in material. If designed as a through bridge the value of $\frac{l}{r}$ or $\frac{l^2}{r^2}$ is evidently considered a matter of indifference, otherwise the upper chord or boom would be subdivided by an efficient lateral system. It is worthy of note in Fig. 6 that it is not considered necessary that the end arches should act even as hip struts or portal braces, and as the hip joint is unbraced laterally the top chord can transmit any transverse strain to earth very inefficiently. These points do not prove that the bridges are defective in strength, but they do indicate an unnecessary use of material. If it is argued that the arches are useful as struts in keeping the chords properly

FIG. 9—CENTRAL STATION, MANCHESTER.

distanced when the train load tends to close them in, from deflection of floor beams, then it may be asked why are they not placed over the hips and each intermediate post? A wasteful use of metal, though regrettable in any case, is not so material for these small spans which are located close to the place of manufacture, but as adopted in the longer suspended span of the Sukker bridge in India such waste is much more important and regrettable. The writer feels sure, however, that if the use of these arches is merely a fashion, their employment in new work will sooner or later be discontinued.

In Figs. 7 and 8 can be seen the manner in which Brindley's famous stone aqueduct is replaced by an interesting swing steel aqueduct carrying the Bridgewater canal over the Manchester ship canal.

Fig. 9 gives an interior view of the Central Railway station, Manchester. Similar roofs are to be seen at the St. Pancras station, London; and St.

Enoch's station, Glasgow. Being free from confusing truss rods and intermediate columns, such stations or depots are very attractive to travelers. The span of the Manchester roof is 210 feet; not so great, however, as the train shed of the Pennsylvania Railroad at Jersey City, built about 1891, which is 252 feet 8 inches between centers of bearing pins.

The object of erecting the tower shown in Fig. 10 was simply to provide additional attraction to New Brighton, and recreation for the crowds of people who annually frequent this popular seaside resort from the neighboring city of Liverpool and the manufacturing districts of Lancaster, Chester and neighboring counties. Since the construction of the Eiffel

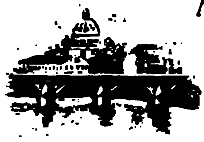
FIG. 10—NEW BRIGHTON TOWER.

Tower in Paris such observation towers have been constructed at Blackpool, New Brighton and other seaside places. They afford excellent views of the surrounding neighborhood, coast, sea, shipping, etc., and in these and other ways are an attraction to visitors.

The examples illustrating this article, though the work of different engineers, are the output of one firm alone, namely, Messrs. Andrew Handyside and Company, of Derby and London, and it is to the managing director of this firm, A. Buchanan, Esq., that the writer is indebted for the illustrations of this article, though for the opinions contained herein the latter is alone responsible.

ALFRED D. OTTEWELL.

BRIDGE EVOLUTION AS RELATING TO SOUTHERN CALIFORNIA



A SYSTEMATIC development is more difficult to trace with reference to bridge design, than in at least a great majority of other lines of scientific work, on account principally of the comparatively recent date of the introduction of metal as the material of bridge construction.

Egypt, as the probable birth-place of civil engineering, would be the natural place to search for the earliest examples of bridge work, but, while the Egyptians were proficient in construction, the crossing of the streams seems to have been accomplished entirely by fording or by ferries. Some small ditches were crossed by flat stones being laid across, one above the other, acting as stone beams or girders (Fig. 1), but there are no remains nor records of any arch bridges or bridge spans

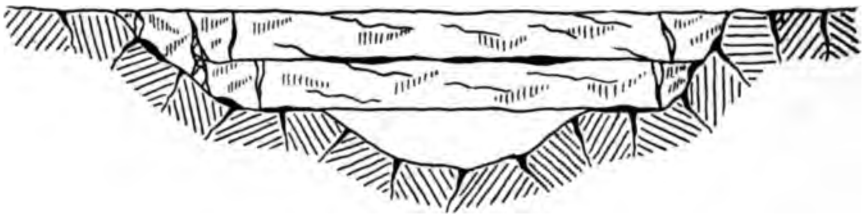


FIG 1—STONE BEAM BRIDGE. EGYPT.

of any other kind. The prototype of the arch is undoubtedly Egyptian, being the inclined stones which covered the chambers and entrances in some of the pryamids.

The oldest known example of the true arch has been shown by Prof. Howe to be one discovered near Babylon in 1894, which was constructed some time previous to the year 4000 B. C., of mud bricks. The real begin-

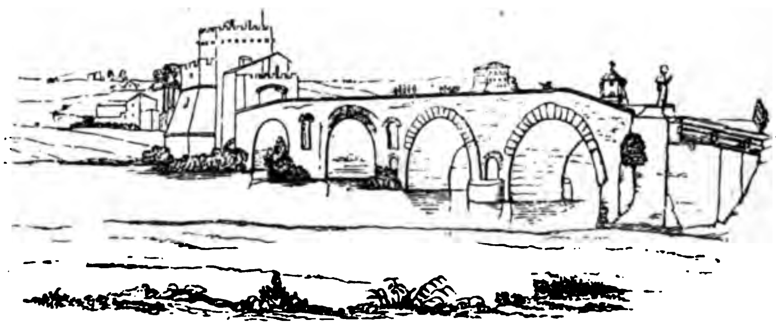


FIG. 2—PONS MILVIUS.

ning of bridge construction was by the Romans in the application of the arch to bridges, at least as early as the year 600 B. C. The oldest recorded example being the Pons Milvius (Fig. 2), located about two miles from

Rome and having six arch spans, of which the largest was 79 feet 9 inches. The Pontus Salarius was another early example, being constructed in 600 B. C. and having five spans from 22 feet 4 inches to 69 feet.

These old bridges were of rather primitive construction, not being designed with the care accorded to contemporary architectural works, but a gradual improvement is noticeable, until during the reign of Augustus there were numerous stone bridges built which have rarely been excelled and seldom equaled in grandeur of design or elaborateness of detail. The best known of these are the bridge at Rimini and the Pont du Gard. It is to the Romans also that credit must be given for the construction of the largest stone arch bridge, which was built at Trezzo over the river Adda about the year 1390 A. D., the span being 251 feet, or 31 feet longer than the Cabin John arch, which is the longest now in existence (Fig. 3).

For the final stages in the evolution of the stone arch bridge we must look to France, where, owing to the placing of their design and construction

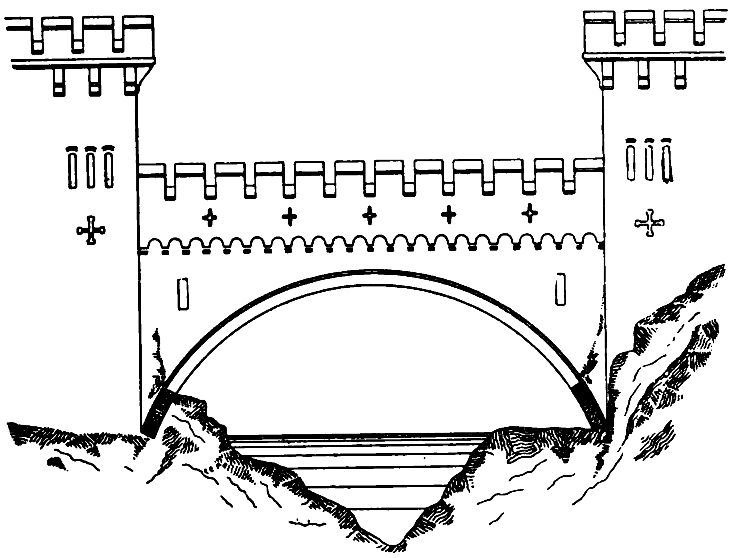


FIG 3—STONE ARCH AT TREZZO. RESTORATION.

in the hands of the engineers of the Ponts et Chaussées, the perfection of detail and harmony in design were given great attention.

The bridge at Neuilly, designed by Perronet, consisting of five 128 feet spans; the bridge of Jena, designed by Lamaude, having five spans of 91 feet 10 inches, and built to commemorate Napoleon's victory of that name, the Pont d'Austerlitz, the Pont Louis Phillipe, and the Auteil Viaduct (Fig. 4), may be cited as examples which will repay much study, and which are of excellent design.

The great expense of stone bridges, and the comparatively small span which was practicable, was the cause of timber being used for bridges. The familiar example of the foot log as the first wooden bridge is well known, but the first wooden bridge recorded of any consequence was the one

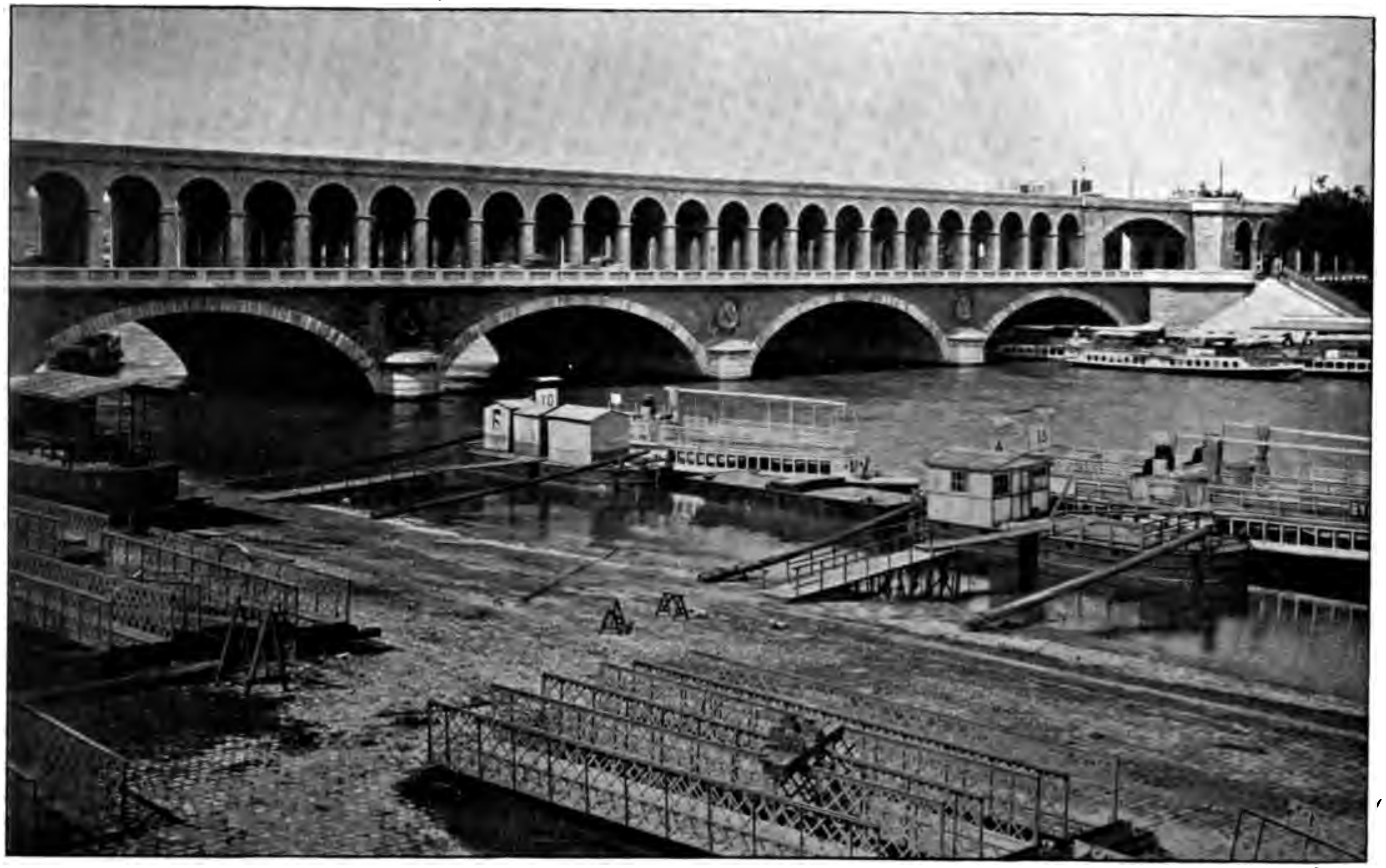


FIG. 4—AUTEIL VIADUCT.

built by Julius Caesar over the Rhine, about 55 B. C., which was a pile structure with about 50 spans.

The very great number of spans in timber built all over Europe renders it impossible to attempt a description of even representative bridges. Such trusses as were constructed were quite unscientific, and the long spans were practically timber arches. Two of the most famous were those of Schauff-

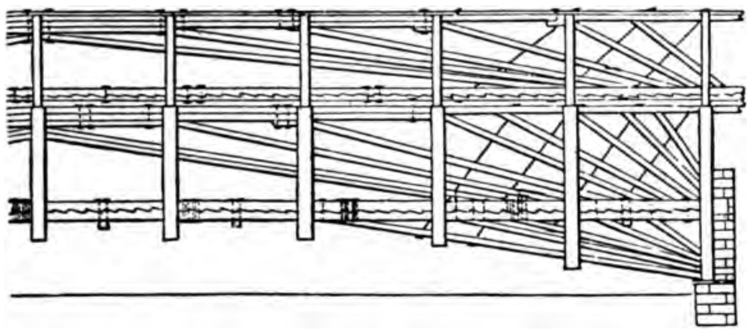


FIG. 5—BRIDGE OF SHAUFFHAUSEN.

hausen (Fig. 5), and built in 1757, and one over the Limmat, built by John Ulrich Grubenmann, the former having two spans of 172 feet and 193 feet, and the latter a single span of 390 feet, which was the largest span ever built in timber. The carpentry was remarkably solid and they were beautiful pieces of work.

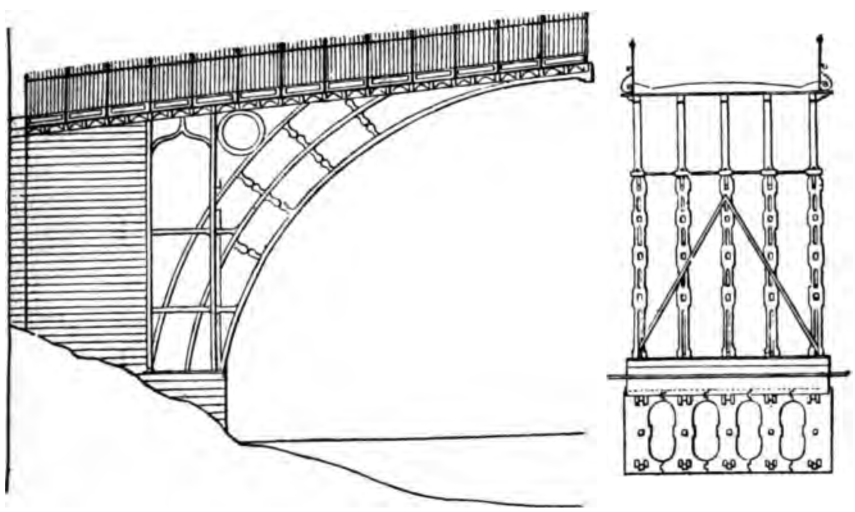


FIG. 6—COLEBROOK DALE BRIDGE.

The first iron bridges were built in England, where bridges of metal were largely used and had reached a quite advanced state of development before they were common elsewhere. Very naturally, as cast iron was better adapted to compression than to tension, the arched form was adopted, and in 1777 a span of 100 feet 6 inches, with a rise of 45 feet, was constructed of

that material at Colebrook Dale (Fig. 6) over the Severn. There were five ribs, which were cast in two pieces each, to meet at the key.

Another at Buildwas of 130 feet was constructed in 1796, and during this year the Sunderland bridge over the Weir, with a span of 236 feet, was constructed from the material designed by Thomas Paine and once erected at Lisson Grove. The original design was presented by Paine to the Academy of Sciences at Paris in 1787. The longest cast iron span constructed was one of the three for the Southwark bridge over the Thames at London, the center span being 240 feet. This bridge, built in 1819, was quite handsome and was designed by Sir John Rennie.

The real beginning, however, of the development of metal bridges was

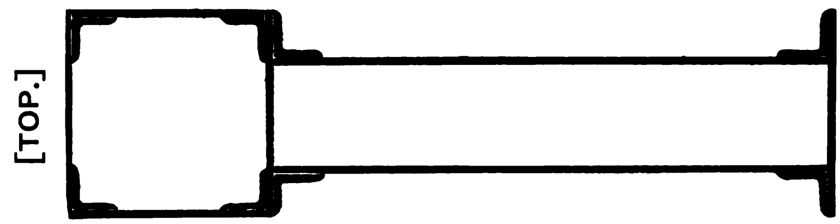


FIG. 7—SECTION OF BOX GIRDERS.

in the use of cast iron girders. For spans up to 40 feet in length, in which, owing to the small tensile strength of cast iron, the bottom flange was made much larger than the top. To extend the span of cast girders it was found necessary to add trussing of wrought iron, but the detailing was very primitive and the largest span of this kind, of 98 feet in the clear over the Dee at Chester, gave way under a train in 1847. The first use of wrought iron for entire girders was made by Fairbairn in 1847, who still retained the large bottom flange. A patent was taken out by him in 1846 for a wrought iron box girder, having a top flange of rectangular box section (Fig. 7), and the first one was built by him for the Blackburn and Bolton Railway. It

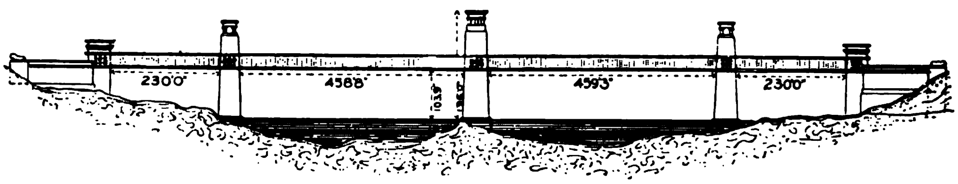


FIG. 8—BRITTANIA BRIDGE.

is of interest to note that the estimate of the cost of such a bridge in 1850, was $146 per ton, or more than three times what it would cost at present. Bridges of this form were constructed of considerable length, that over the River Trent having two spans of 154 feet each.

The great tubular bridges designed by Robert Stephenson, the Conway bridge with a span of 400 feet, the Britannia bridge (Fig. 8) with two spans of 230 feet and two of 460 feet, and the Victoria bridge at Montreal, which has just been replaced by an American pin connected bridge, were

of essentially this form of construction and were the culmination of the system.

The subsequent development of bridge building, both in England and on the European continent, was scarcely more than a modification of these solid plate constructions into multiple lattice trusses (Fig. 9), and for the logical development of the modern truss bridge we must turn to the United States, where the engineers were under the necessity of exercising great economy, and for this reason seldom built stone bridges, and used but little iron in their trusses. The bridge over the Delaware at Trenton (Fig. 10) was constructed in 1804 from the plans of Mr. Burr, the spans

FIG 5.—VALLEY BRIDGE, SCARBOROUGH. ENGLISH LATTICE.

being through timber arches with iron suspenders to support the floor, the longest opening being 200 feet.

The Town lattice was a multiple lattice bridge, made of plank crossing at right angles and treenailed at the intersections, the top and bottom chords, also of plank, were treenailed to the diagonals. This form of bridge was largely used on railroads and also for highways, one at Richmond, Va., having spans of 150 feet.

The Fairmount bridge over the Schuylkill at Philadelphia (Fig. 11), designed by Louis Wernag, had a trussed arched span entirely of timber, with a span of 340 feet.

The gradual modification of wooden bridges, led to the invention in 1840 of a truss bridge by William Howe, in which the chords and diagonals were of timber and the *verticals* of iron, and in 1844 the Pratt truss was

invented, in which the chords and verticals were of timber and the *diagonals* of iron. Both of these bridges met with great favor and are still very much used in new countries or where timber is cheap and plenty. The railroad bridges about Los Angeles are many of them excellent examples of the Howe truss, especially the one on the Southern Pacific's line to the north over the Los Angeles River, while the majority of the city bridges are Pratt trusses, with the improvement, however, over the original design, of iron bottom chords and pin connections. A Howe truss bridge designed by the writer about eleven years ago for 92.3 ton engine loading is shown in Fig. 12.

Probably the earliest form of an all iron bridge was the Bollman sus-

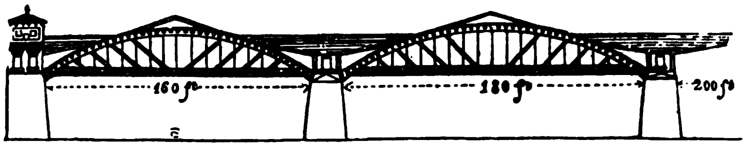


FIG 10.—DELAWARE BRIDGE AT TRENTON.

pension truss (Fig. 13), which was much used on the B. & O. R. R. between 1840 and the beginning of the Civil War.

The Whipple truss (Fig. 14), in which the main diagonals reached over two panels, was first used near Troy, N. Y., in 1852, the span being 146 feet, and the first example of a really modern bridge. It was pin connected, with cast iron compression members and wrought iron tension members.

From this time on we find the various types of timber bridges undergoing the transformation into metal bridges, with varying success, until at the present time there is only a survival of the fittest systems of triangulation. The application of iron to all the members of the Howe truss was made in various ways. At Ashtabula, Ohio, a span of this kind was built in which the compression members were made up of several I beams side by side, and had the designer known enough to so connect the separate

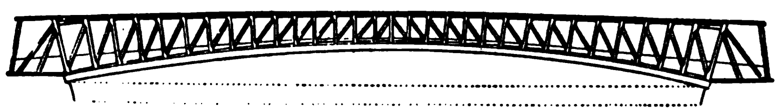


FIG. 11—FAIRMOUNT BRIDGE OVER SCHUYLKILL.

pieces composing one member, that they would act together, all might have been well. But the end came in the frightful Ashtabula disaster, and further attempts to construct the Howe truss in iron, for which it was ill adapted, have been abandoned.

The Whipple truss, as well as some others of double or multiple intersection systems, were for a long time favorites for long spans, having been used in recent years by one of the most prominent of American bridge engineers, but now all engineers in this country seem agreed upon the rejection of those forms which have any ambiguity of stresses.

The Pratt truss, which did not meet with so great favor as the Howe truss when wooden compression members were used, proved the best

FIG. 12—HOCKING VALLEY RAILWAY. HOWE TRUSS.

adapted for metal bridges, and is now used for the great majority of truss bridges up to 200 feet in span. For greater lengths than this the sub-panel Pratt or Baltimore truss is most frequently used (Fig. 15), although in some recent designs for steel bridges from 230 to 500 feet span, the writer found the Pratt truss, with curved top chord and long panels, to vary

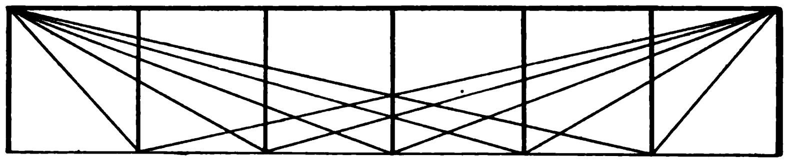


FIG. 13—BOLLMAN TRUSS DIAGRAM.

little in cost from the sub-divided truss, besides making simpler shop work and cheaper erection.

Another form of truss which has been found well adapted to metal bridges is the triangular or Warren system, and with the system of sub-trussing adopted in the 400 feet span of the old Louisville bridge it is very

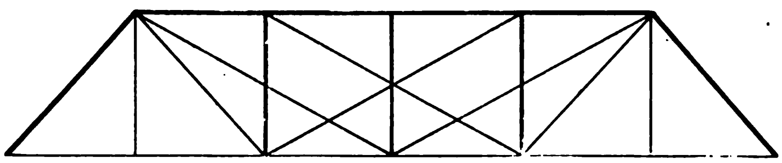


FIG. 14—WHIPPLE TRUSS DIAGRAM.

simple and quite economical for long spans. The simple Warren truss being the most scientific form in use—in the language of a former chief of the writer's, "the load is always traveling toward the abutment."

With the forms of trusses so well fixed upon, the tendency of recent years has been toward the bettering of the detailing, and endeavor has

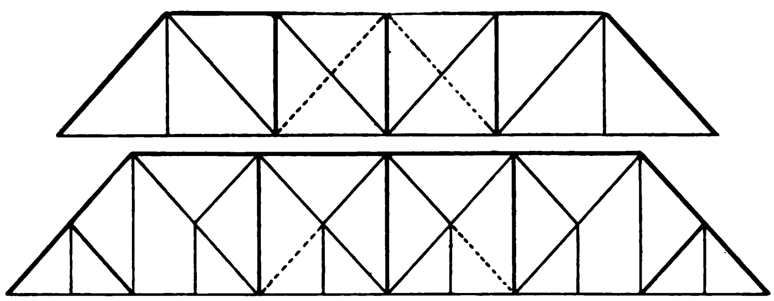


FIG. 15—PRATT AND SUB-DIVIDED PRATT DIAGRAMS.

been made to formulate detailing into a system, or to have adopted a standard specification. To do this would to a great extent destroy the individuality which has been the true cause of advance, and check to some extent further improvement..

C. E. Fowler
M. Am. Soc. C. E.

[*To be Continued in June.*]

CHEMICAL AND PHYSICAL CONSTITUTION OF STEEL

[*Concluded from April Number.*]

IN 1895 Mr. H. H. Campbell made an investigation on 1,920 pieces of two by three-eighths-inch bars rolled from small ingots of acid and basic open-hearth steel. These pieces were tested as they came from the rolls, and drillings were taken from the test-pieces. The results were divided into 137 groups. He says:

"After forming these groups, the average manganese, sulphur, phosphorus and ultimate strength of each were calculated from the records, while the average carbon, silicon and copper were determined by weighing an equal quantity of drillings from each bar, and making a chemical analysis, the carbon being determined by combustion."

Mr. Campbell attempted by the method of least squares to work out the values for each element, but his results were unintelligible, and he remarks:

"It is with no little disappointment that I am forced to confess that further investigation throws grave doubts on the validity of this method of least squares when applied to such a number of unknown quantities, and when any one of these quantities is of very little importance."

He then neglected the effect of silicon, sulphur and copper, and obtained several results for each of the elements, in the order in which they are given below, for each class of steel. In the latter part of his investigation he considered a new series of acid and basic steels. This gave him for the acid steel fifty-six groups in the new series, as against seventy groups in the first series. For the basic steel he had seventy-four groups in the first series and seventy-two groups in the new series.

The values he has adopted may be summarized as follows: Mr. Campbell's values for pure iron and increase due to .01 per cent of carbon, phosphorus and manganese, in pounds per square inch. In b and e for Acid Steels, and in g and j for Basic Steels, the increase due to manganese was not considered. Mr. Campbell remarks, regarding the value of 1,444 pounds for phosphorus in j, "This value of phosphorus was not sustained by any other evidence."

The factor R represents an allowance for the conditions under which the piece is rolled, whether finished hot or cold. In the present series of groups it is zero."

ACID STEELS.

	C.	P.	Mn.	Pure Iron.		
a Old series,	1529 +	1316 +	39 +	34,326		= Ultimate Strength.
b Old series,	1485 +	1260		+ 33,000		= Ultimate Strength.
c New series,	1126 +	716 +	3 +	40,439		= Ultimate Strength.
d Old series,	1368 +	1068 —	23 +	37,544		= Ultimate Strength.
e Both series,	1210 +	890		+ 38,600	+ R	= Ultimate Strength.

BASIC STEELS.

	C.	P.	Mn.	Pure Iron.		
f Old series	1035 +	941 +	53 +	38,996		= Ultimate Strength.
g Old series,	1085 +	1200		+ 40,000		= Ultimate Strength.
h New series,	935 +	939 +	114 +	36,335		= Ultimate Strength.
i Old series,	1035 +	941 +	53 +	38,996		= Ultimate Strength.
j Both series,	998 +	1444		+ 39,987		= Ultimate Strength.
k Both series,	950 +	1050 +	85 +	37,430	+ R	= Ultimate Strength.

Mr. Campbell estimated the ultimate strengths of each of his groups by several of the above values, and the difference between the estimated ultimate strengths and the average actual ultimate strengths of the groups were small in most cases for each class of steel, but the best results were obtained by the last values given in the above tables.

Mr. Campbell's conclusions were as follows:*

"1. The strength of pure iron, as far as it can be determined from the strength of steel, is about 38,000 or 39,000 pounds per square inch.

"2. An increase of .01 per cent of carbon raises the tensile strength of acid steel about 1,210 pounds per square inch, and of basic steel about 950 pounds. This difference between the effect of carbon upon acid and basic steels, as found by mathematical analysis, is corroborated by the graphic records in Figs. XX. and XXI.

"3. An increase of .01 per cent of manganese has very little effect upon acid steel unless the content exceeds .60 per cent, but it raises the strength of basic steel about 85 pounds per square inch.

"4. An increase of .01 per cent of phosphorus raises the tensile strength of acid steel about 890 pounds per square inch, and of basic steel about 1,050 pounds.

"5. The following formulæ will give the ultimate strength of ordinary open-hearth steel in pounds per square inch, the carbon, manganese and phosphorus being expressed in units of .001 per cent, and a value being assigned to R in accordance with the conditions of rolling and the thickness of the piece:

FORMULA FOR ACID STEEL.

38,600 + 121 Carbon + 89 Phosphorus + R = Ultimate Strength.

FORMULA FOR BASIC STEEL.

37,430 + 95 Carbon + 8.5 Manganese + 105 Phosphorus + R = Ultimate Strength.

"6. The metals from which these data were derived were ordinary structural steels ranging from .02 to .35 per cent of carbon, and it is not expected that the formulæ are applicable to higher steels or to special alloys.

"7. A considerable difference may be found between steels which appar-

* The Manufacture and Properties of Structural Steel, New York, 1896. pp 329-331.

ently are of the same composition, and which, as far as known, have been made under the same conditions.

"8. In the case of acid steel, an increase in manganese above .60 per cent will raise the tensile strength above the amount indicated by the formula, the increment being quite marked when a content of 80 per cent is exceeded.

"9. In steels containing from .30 to .50 per cent of carbon, the value of the metalloids is fully as great as with lower steels, while the presence of silicon in such metal in proportions greater than .15 per cent seems to enhance the strengthening effect of carbon.

"10. In steels containing less than .25 per cent of carbon the effect of small proportions of silicon upon the ultimate strength is inappreciable.

"11. Sulphur, in ordinary proportions, exerts no appreciable influence upon the tensile strength.

"12. Both acid and basic steels containing less than .30 per cent of manganese give an actual strength greater than is shown by the formula, and when this is taken in connection with the abnormal strength of the unusually pure metal shown in Group 198 of Table 131, it is indicated that oxide of iron raises the ultimate strength."

In an investigation of this kind the tests should be considered individually, as, when they are grouped, you get average chemical compositions and a more constant relation between the elements—say, for instance, between carbon and manganese. In this way you are liable to give to one element part or all of the effect of another element. If the elements increase or decrease in the same proportion, the estimated values meet the conditions very well. I tried grouping the tests, and soon found that it was not as satisfactory a way as using the individual tests.

Mr. Campbell says, regarding effect of thickness:

"The effects caused by variations in rolling-temperature appear in their most marked degree in the comparison of plates of different gauges. It is not customary to test the same heat in several sizes, but by long experience the manufacturer is able to judge the relative properties of each thickness. The heads of two widely known plate-mills have given me their estimate that, taking one-half inch as a basis, there will be the following changes in the physical properties for every increase of one-quarter inch in thickness:

"1. A decrease in ultimate strength of 1,000 pounds per square inch.

"2. A decrease in elongation of 1 per cent when measured in an 8-inch parallel section.

"3. A decrease in reduction of area of 2 per cent.

"W. R. Webster gives the same data on ultimate strength, but does not mention the relation of section to elongation.

"It is, therefore, plain that in the writing of specifications some allowance must be made for these conditions, since a requirement which is perfectly proper for a three-eighths-inch plate will be unreasonable for a one and one-half-inch. Moreover, the effect is cumulative, since a harder steel must be used in making the thick plate, and this will tend to lessen the ductility rather than make up for the reduction caused by the larger section. In plates below three-eighths-inch in thickness it is also necessary to make allowances, since it is almost impossible to finish them at a high temperature, and the test will give a high ultimate strength and a low ductility."

By arranging in tables, constructed on some general form, the values of

carbon, phosphorus and the other elements as given by different investigators, it is made an easy matter to use the value of one element adopted by any given investigator with those of one or more elements as used by other investigators. In this way a much wider range of values can be covered, and indications sooner reached of the modifications or corrections required in value to meet any given condition of rolling. From the results that we have up to the present time, all that can be said is that we are no doubt on the right track, although there is much work to be done before we arrive at the final solution of the problem. I think that we should feel very much encouraged with the progress already made, and should renew the attack with increased vigor. The actual use of chemical data by the steel works in their ordinary everyday practice of grading the steel, and applying it to their orders, is much greater than is ordinarily supposed. This will in itself in a few years, solve many of the points that are now giving us trouble.

The objection has been raised that the chemist only gives the total carbon present in the steel, and not the condition in which it exists, and that we cannot expect to predict from this total carbon what its physical effect will be, as in one case we may have much more of the hardening carbon present than in another for the same total carbon reported. This objection is not as important as it seems; for the form of the carbon present depends largely on the heat-treatment, and that is again modified by work of rolling; therefore, if we take any given grade of steel, and by experiment determine the physical effect of different heat-treatments in connection with work, we have the direct answer instead of waiting for the proportion of hardening carbon present to be given by the chemist or the microscopist. We know to-day that as carbon increases, the differences due to heat-treatment or finishing-temperature in rolling are much greater than in the lower carbon steels. This is no doubt due to the greater change in the form of the carbon present. It calls for a little more leeway between the high and low limits of ultimate strength in specifications, and much closer vigilance as to heating and finishing temperatures in rolling the higher steel. Microscopic examinations will, of course, be of the greatest service in this connection, and will give us definite information on many points that are now in doubt. The microscopists have not as yet seriously taken up the solution of this problem, and to-day we do not know how the different fractures of steel, due to well-known changes from heat-treatment, would appear under the microscope, and we could not recognize them. Then, again, the grain referred to by Mr. Sauveur and others is not the same grain that we refer to and are familiar with in ordinary practice. I look forward to great results from the microscopical investigators coöperating with chemical analyses and the study of heat-treatment in connection with work.

In this practical age it will be asked, "What is the actual value of all this, and is it worth while to bother any more about it?" The answer is that already the steel-maker depends more and more every year on the very points that we have been discussing, and the engineer should know what he is doing when he uses both chemical and physical limits in his specifications. Is it to be wondered at that to-day we have specifications in which the chemical requirements do not at all agree with the ultimate strengths specified? This in the ordinary home-orders may make very little difference.

as it is an easy matter to investigate and make proper modifications required, but in specifications from foreign railroads or engineers at a distance, for material on export orders, it is a very different matter. There is no time to refer questions of this kind, and the inspector is sometimes forced to condemn material that he knows from experience is all right. It may give better physical tests than were called for but not conform to the chemical requirements in the particular specifications in question, though it would meet both the physical and chemical requirements of our leading engineers and railway companies in this country. Some of these foreign specifications are so worded, and the requirements are such, that it is not safe for an American manufacturer to bid on the orders. This may be due in part to their not understanding all of the conditions under which the tests are to be made. In other cases it seems as though modifications must have been made on previous orders, either in the chemical requirements or physical tests called for, as no steel was ever made that would meet all the requirements of chemical and physical tests in some such specifications.

Many export-orders for rails call for phosphorus not over .06 per cent, while the sulphur is allowed a much higher limit, or not specified at all. This low phosphorus cuts out several of our largest steel-works, whose material will meet all of the physical-tests called for, being low in sulphur and under .10 per cent phosphorus, and giving entire satisfaction to our leading engineers and railroad companies. The foreign manufacturers of basic Bessemer steel and low-phosphorus acid Bessemer steel are working the low-phosphorus clause for all it is worth, just as our manufacturers would do under similar circumstances; but we, as engineers, want to know if there is any good reason for this distinction, which is made on account of local conditions, and if the high sulphur is not as undesirable as the phosphorus would be up to the limit of .10 per cent usually allowed in this country?

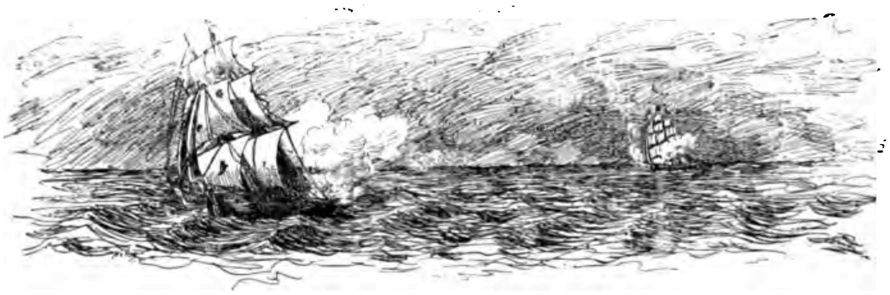
This is a matter that should be thoroughly discussed and on which opinions should be secured from our leading engineers; for it is of no use for the manufacturers to give their opinion unsupported by the experience of users of their rails. It is just here that the effect of the different elements plays an important part. Our manufacturers know from experience that as their phosphorus is a little higher than the limit of .06 per cent referred to, they must keep the other elements inside of given limits to produce the best results in the finished rails. This is done successfully, and a rail is produced that will meet the requirements of the drop-test and give satisfaction in use. I do not wish to be understood as advocating high-phosphorus, but my position is, that rails which will meet all of the varying conditions in this country will meet all that is required of them when put in use in other countries. If one examines the methods of manufacture of rails in this country and those in other countries, then visits the countries where our rails are being introduced, and gets accurate information as to the service they are giving, he will be convinced that there is a great future for America in the export business in rails.

The conditions with regard to the material for bridges are about the same. Foreign specifications, in many cases, provide that only acid open-hearth steel can be used. This has already prevented our bridge-builders from bidding upon thousands of tons of bridge work, although in some cases they have accepted the requirement of acid open-hearth steel, and have taken

the orders. In other cases they have explained that our government is using the basic open-hearth steel; that in the manufacture of it the works here start with an iron very much lower in phosphorus than is ordinarily used, and that the resulting steel is much more uniform. This has had a great deal of weight, and the use of basic steel has been allowed in some cases. In other cases new specifications have been adopted after investigation in accordance with the best American practice, which allows the use of either basic or acid open-hearth steel. I refer to this matter at length, as it is of the greatest importance to our engineers and manufacturers, as well as to all others who wish to see our export trade developed.

The continued discussion on the physics of steel is broad enough to take up any specifications on home or export orders that may be brought forward; the uniform methods of testing and methods of manufacture and rolling that will improve the finished products. It is of the greatest importance to establish the quality of American material abroad, and to have on record all facts regarding the same, both from the engineers' side and the manufacturers'.

WILLIAM R. WEBSTER



THE ARCHITECTURE OF BRIDGES, PARAPETS AND BALUSTRADES

NO feature of a bridge is seen more often, nor commented upon so frequently as the parapet wall, railing or balustrade. No matter how elegant the structure itself may be, nor how solid the character of the construction, if a light, poorly designed or inharmonious style of parapet or railing is used, the artistic appearance will be to a great extent marred or damaged. For building work the architect makes the design for a parapet or balustrade, fixing upon the exact dimensions for each part or moulding, and the artisan constructs it accordingly. For bridge work, upon the other hand, it is the usual custom to make the design conform largely to the sizes of building material which can be most readily obtained. The height of a parapet is limited to some dimension between three and four feet if it is to be used on a municipal structure, usually three feet six inches.

A masonry parapet for the abutment wall of a bridge approach should be either of solid construction or else the dado should have less openwork than

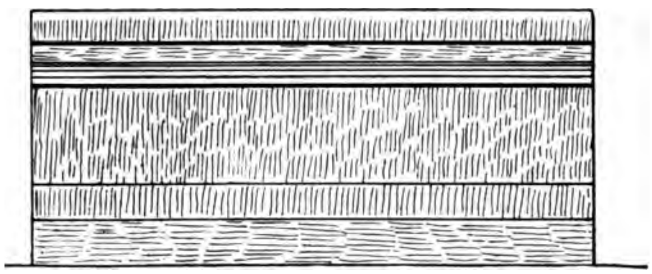


FIG. 1.

the parapet of the bridge itself; the same principle applying to the parapet on a stone arched approach to a steel bridge, a splendid example being the parapet balustrades of the Washington bridge over the Harlem, or the Westminister bridge over the Thames. Where stone is used the dado or center portion of the parapet should be made solid (Fig. 1), as the effect will be just as good and the cost much less; if brick is used, the dado may be laid with open work (Fig. 2) or else different colors of brick may be used and a pattern worked into the construction (Fig. 3), although the contrast should be very slight or else the result will be too loud; where cement or terra cotta work is employed, the solid dado may have panels of relief work with fine effect (Fig. 4). The extreme ends of the approach parapets and the ends next to the bridge itself should be terminated by panels or pedestals of harmonious and appropriate character (Fig. 5). The proportions used should be decided upon with reference to the general style of the structure, the simpler and plainer the design the more likely it will be to please for a long period of time. The proportions of the pedestals

of the Roman classic columns have been used with splendid success in establishing the dimensions for the plinth, dado and capping of parapets, the whole being coped or covered with a simple cap (Fig. 6).

The design of the parapet for masonry arches should be such as will give the best effect to the arch itself. Where the depth of the center is

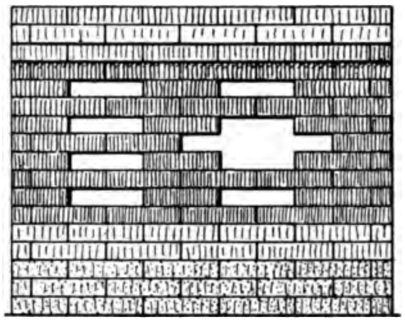


FIG. 2.

very shallow, the parapet should be of solid or close construction similar to that on the Wheeling arch (Fig. 7), which is a simple design of stone wall with a plain coping, or like that of the Wissahickon arch at Philadelphia, with pedestals at frequent intervals (Fig. 8). Another example of solid parapet where the work is finished instead of rock face is that of the Darlaston bridge (Fig. 9), the base and coping having chamfered

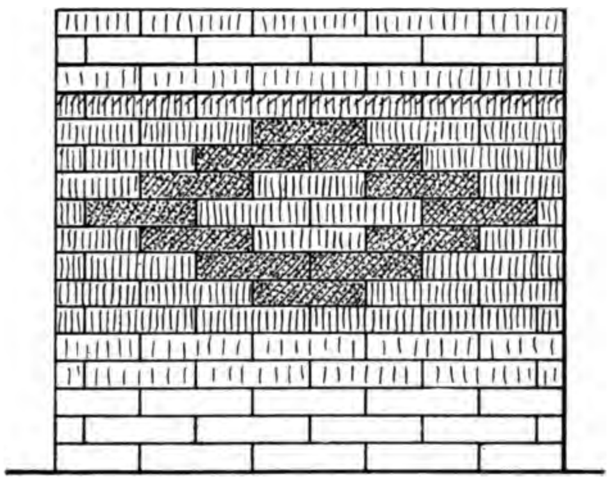


FIG. 3.

edges. Where dressed stone is used the dado may be divided into panels, with decorations in relief, as was mentioned for approach parapets, or a solid effect may be obtained by the use of a design similar to Fig. 10, which is the parapet of the Ouse Valley viaduct in England, the base being beveled on the outer edge and supporting a series of small arches, above which is a top course with chamfered edge and an ornamental cap with curved

top (Fig. 11), being a section which shows the coping or cornice of the bridge.

This design would also be the type to use where the depth is only moderately great, but where the depth is great an open parapet railing or balustrade should be used, an extreme case being the Croton Aqueduct High Bridge at New York, the depth over the crown of the arch being so great, to allow room for the water pipes, that a light cast iron railing is a most appropriate parapet.

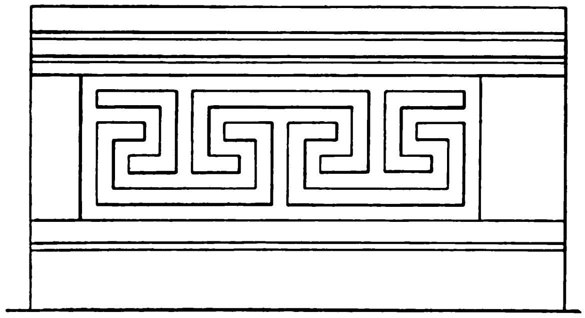


FIG. 4.

The cast iron parapet (Fig. 12), used on the Gerrard's Hostel bridge at Cambridge, England, is an elegant design with open dado of lozenge pattern, and heavy enough for a span with only moderate depth. Another English design of cast railing is shown in Fig. 13.

The most notable bridges have parapets of more elaborate design and more expensive construction, using most frequently a balustrade with turned stone balusters. The Wellesley bridge at Limerick, designed by Mr. A. Nimmo, is one of the handsomest bridges in the British Isles. There are

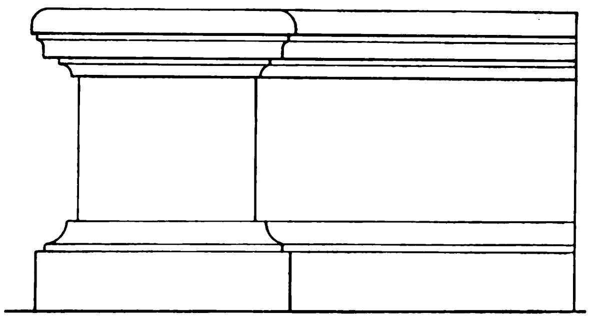


FIG. 5 AND 6.

five elliptical spans of 70 feet each, surmounted by an elegant balustrade (Fig. 14), there being two pilasters over each arch dividing the balustrade into three portions over each span, with pedestals at the extreme ends and over each pier. The recently constructed Schenley Park bridge at Pittsburg has one of the handsomest balustrades, with turned stoned balusters, in this country.

They are more frequently employed on European work than elsewhere, the oldest examples probably being the bridges of Venice and notably the

bridge of the Rialto. The Auteil viaduct at Paris also has such a balustrade as have numbers of other French bridges. We might, therefore, conclude that this forms the most appropriate parapet railing for an elaborate stone bridge.

FIG. 7.

The new bridge at Ayr, Scotland, has a parapet of stone in which the dado is decorated with moulded circular openings and such other details so as to make a very handsome design (Fig. 15). The parapet has pedestals at the ends and over the piers, surmounted by lamps, and five intermediate pilasters or pedestals over each arch.

FIG. 8.

The railing or balustrade of bronze used over the spans of the Washington bridge, is of a design which gives a very similar effect.

The use of a simple battlemented parapet has been used on many stone bridges with good effect, but would be more suitable for a railway bridge

than for a highway structure, unless the embrasures were filled with simple iron pickets.

Toll or gate houses were formerly much employed at the extreme ends of parapets, when toll bridges were more numerous, and some of the more recent bridges have used large end pedestals in imitation of these, but they should be of simple design, unobtrusive in size and harmonious with the parapets and the structure itself.

The use of terra cotta balustrades has been referred to, and as their use is quite frequent and the methods of construction similar to those of concrete, which are made up of sections formed in molds, we will quote

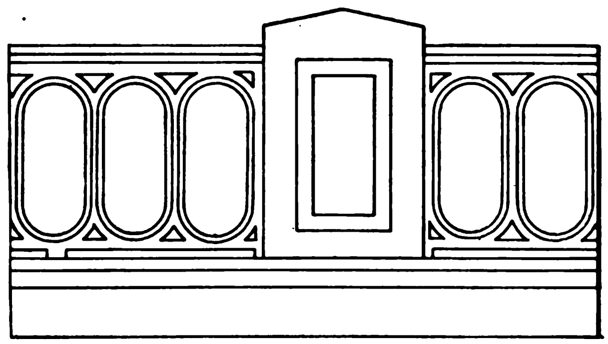


FIG. 9.

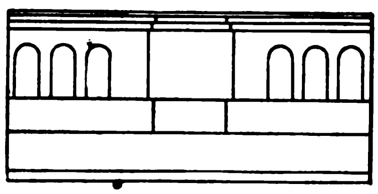


FIG. 10.

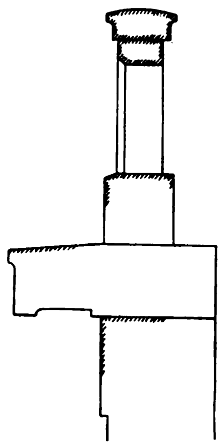


FIG. 11.

at length from a recent article by Mr. Thomas Cusack in *The Brickbuilder:*

"We give at Fig. 16 one section of parapet balustrading, which, whether by accident or good intention, proved well within the capabilities of the material in which it was made. This is due to the harmonious relationship of the members, also to the nice ratio of voids and solids obtained in fixing the size of these members. In this way a uniform shrinkage was secured, equalizing the strain during that critical process. The piece before us is 2 feet 6 inches by 3 feet, and but 4 inches in thickness. There was no difficulty experienced in the execution of a score such pieces, and the size might have been increased considerably (had that been necessary) without

incurring serious risk. With a thickness of 6 inches, single pieces such as this would be quite practicable up to, say 3 by 4 feet; even at that size, we doubt whether the limit would be reached.

"At Fig. 17 we have a piece of balcony balustrade of the same general character. It is set up temporarily in connection with the dies and capping the better to illustrate both design and construction. In trueness of line,

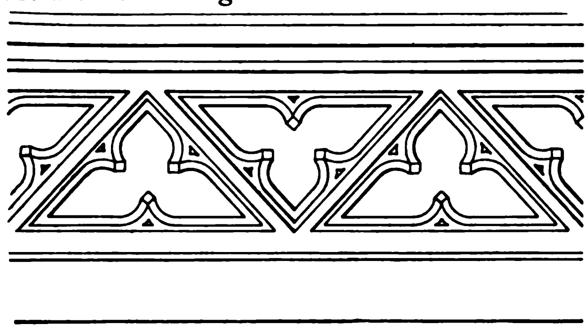


FIG. 12.

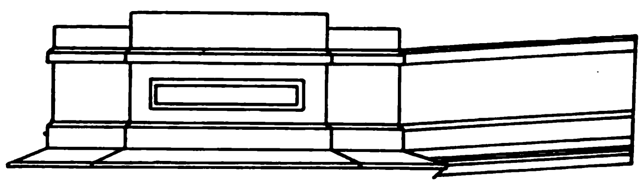


FIG. 13.

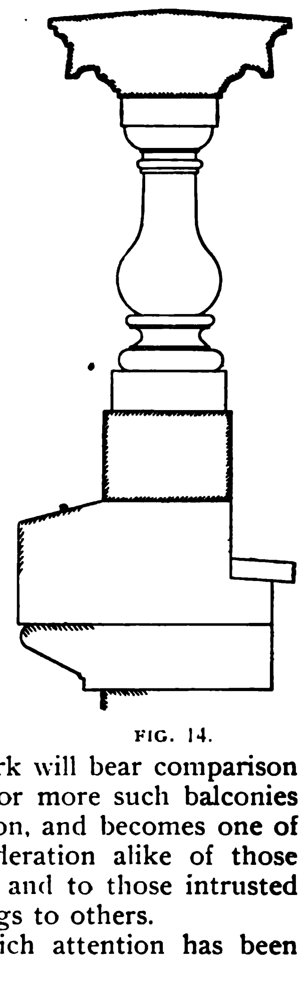


FIG. 14.

as in other points of mechanical excellence, this work will bear comparison with the best cut stone. As for price, where two or more such balconies are required, it ceases to be a question of comparison, and becomes one of contrast. We commend these facts to the consideration alike of those who seek adequate returns on a given investment, and to those intrusted with the beneficial expenditure of that which belongs to others.

"The balcony and parapet balustrading to which attention has been

directed in the foregoing illustrations, are all associated with classic, or with some phase of Renaissance architecture. For the remaining example in that class of work, a distinct type of Gothic has been selected, from which it will be seen that pierced curvilinear forms, however elaborate, are well within the capabilities of burned clay. Indeed, we may go farther and say that, in comparison with stone, the advantages in favor of the plastic material will be found in proportion to the intricacy of the design. This becomes obvious on taking the actual value of the stone in the rough, adding to it the cost of punching out the voids through a thickness varying from 4 to 8 inches. Thus far we get the subject in outline only. An expert stone-cutter has yet to mold all the members, to quirk out the intersections, and cut a variety of cinctures before it is complete. In figuring out the relative cost, it will be well to remember that, in stone, all this is done by the persistent, laborious use of mallet and chisel; finally, that the

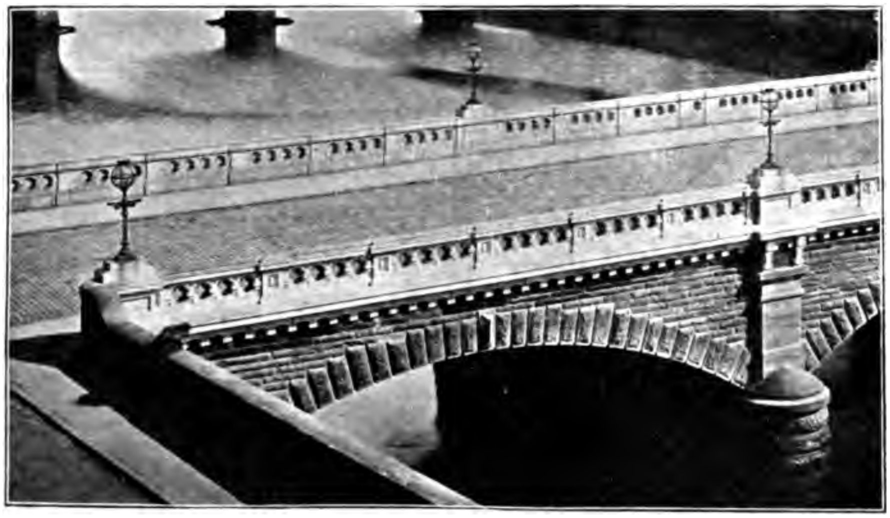


FIG. 15.

man who handles these tools is—as indeed he ought to be—one of the highest paid mechanics employed in connection with building. Gothic tracery in stone is therefore a luxury, reserved for the few who can afford it. Executed in burned clay, it comes within the reach of all builders wise enough to seek an embodiment of the artistic with the utilitarian elements of architecture, therein to be obtained at reasonable cost. Here we have the sound democratic doctrine of Mill—'the greatest good of the greatest number'—fittingly perpetuated.

"In the production of pierced work in terra cotta, whether bounded by straight or curvilinear lines, the operations just referred to are reversed from the outset. Even to cutting the profile of a molding in zinc, the part that a stone-cutter throws away as useless is indispensable to the terra cotta maker. Mounted on a wood backing, it becomes his templet, from which the same molding is run with but little effort in a semi-fluid and very mobile material. Advantage has been taken of the quick setting and adhesive

properties of plaster, an equally rapid system of manipulation has been evolved. In this the expert plaster worker is guided by well-defined rules of procedure, all of which have been suggested to him from time to time by the peculiar action of the material in which he works. Chief among these is the principle of casting, wherever possible, as distinguished from carving in the solid. Hence the plaster model, no less than the mold to be taken from it, assumes the desired shape during the *process* of setting, and before the mobile mass has solidified. It may, therefore, be said that the resulting molds represent the least possible expenditure of raw material, of time, and

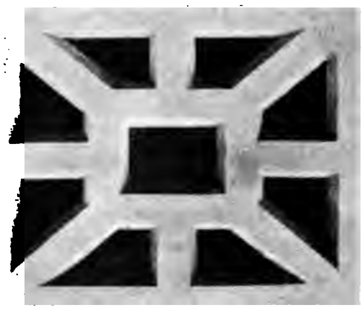


FIG. 16.

FIG. 18.

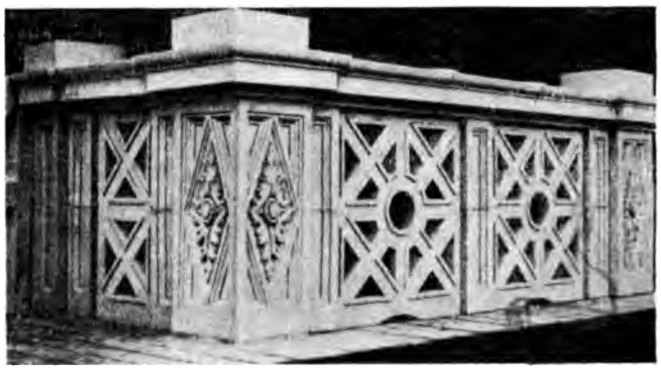


FIG. 17.

of mechanical effort. So much for the preliminary steps of procedure; which, like the working drawings, are but well-devised instruments of service,—a means to an end, not to be confounded with the end itself.

"In producing the actual pieces of terra cotta from these easily prepared molds, the conditions are not less favorable. The raw material covers a goodly share of the earth's surface. Its abundance, variety, and wide distribution make it available for all time at a nominal cost. The facility with which it can be pressed into shape is proverbial; for here, too, the process is strictly plastic throughout. From thirty to fifty pieces may be produced from each mold, without the aid of any tool whatever, beyond

the use of a man's hands. It is a fact, worthy of more than passing notice, that work such as shown in the accompanying illustration was *not* hammered out of rock by oft-repeated blows and knocks, but molded in soft clay, that unresisting yields itself to the touch.' The last dozen words show that this easy facility of execution appealed to the poetic imagination of Longfellow no less strongly than it does to the most prosaic of practical men, to whom 'time is money.' To the fully equipped and qualified achitect it should have a two-fold significance; for in him we expect to find these qualities of temperament and training united to an extent unlooked for in the members of any other profession.

"In this connection, we would call special attention to Fig. 18 showing a view of three pieces of Gothic balustrading. It will be seen that the shaft by which these two alternating designs are, apparently, separated, is made to lap in such a way as to unite them, at the same time rendering the one and only joint practically invisible. In short sections the diagonal stays would not be needed; but as this was one of considerable length, they were added as a safeguard against lateral vibration. The spacing of these sections was, of course, fixed arbitrarily by the design, but the jointing and general construction were intrusted to the terra cotta manufacturer. They might—by some makers would—have been subdivided into an aggregation of small pieces, on the erroneous supposition that this would mean less risk and less responsibility."

ALBERT FINK*

IT is given to few engineers to achieve greatness in more than one specialty. The profession now comprises so many branches that few can reap distinction in more than one particular. Some become eminent as investigators, or as constructors, or as managers, but the capacity to excel in all those directions is seldom found in the same man. But it can be said of the late Albert Fink, that in the early part of his career he ranked as the leading bridge engineer of this country. Later he made a great reputation as an investigator of railroad economics, and as a railroad manager under exceptional difficulties; he gained still higher fame as a statesman, directing an association of railroads, and making most valuable contributions to the rational solution of the railroad problem.

He was born in Lauterbach, Germany, October, 1827, and received his early education in his native town in a private school, in which boys were prepared for the university course, much attention being there paid to the study of Latin and Greek. His father was an architect, and, as Albert evinced a desire to follow this profession, he was sent to the polytechnic school at Darmstadt, where he took a course in engineering and architecture, graduating with high honors in 1848. From there he went to Offenbach, near Frankfort-on-the-Main, entering the service of a contracting firm engaged in the construction of public buildings, factories, and dwellings, and there he gained much practical experience in his profession. The German Revolution of 1848, in which, as an ardent lover of freedom and a firm believer in democratic institutions, he took a deep interest, proving a failure, and the consequent reaction producing a most unfavorable condition of things, he decided to emigrate to America. He returned to his home early in 1849 to prepare himself for the important step he was about to take, by thoroughly reviewing his polytechnical course and by studying the English language. He was already exceedingly systematic, and made for himself a schedule of daily studies, allowing nothing to distract him from the performance of the task he had imposed upon himself, being fully determined to omit nothing that he could do to achieve success in life.

In the spring of 1849, the year in which so many young Germans left their fatherland, he came to America. Few men were better equipped than he for the battle of life, and none had more courage to engage in it. Nevertheless, he found much difficulty in getting a start, and his courage, patience, and power of endurance were severely tried before he finally succeeded in obtaining congenial employment. In New York, where he landed, he was unable to do so, but soon after his arrival in Baltimore he had the good fortune to get a position in the drafting office of Benjamin H. Latrobe, one of the first great engineers this country produced, who was the chief engineer of the Baltimore and Ohio Railroad, then under construction.

In those days engineers and draftsmen who could make original designs were not as plentiful as now, and such work fell almost entirely upon the

*A biographical sketch, adapted from Transactions Am. Soc. C E.

chief engineer. So it was natural that Albert Fink's thorough schooling and his practical experience should cause him to soon attract Mr. Latrobe's favorable attention and cause his rapid promotion. It was not long before he became Mr. Latrobe's principal assistant and was put in charge of designing and building bridges, stations, and shops for the new road between Cumberland and Wheeling, a position which he retained until the completion of the line, in 1853. During this time he produced some of his best engineering works and invented his well-known truss, which enabled him to increase considerably the length of span in iron bridges.

ALBERT FINK, AGE 30.

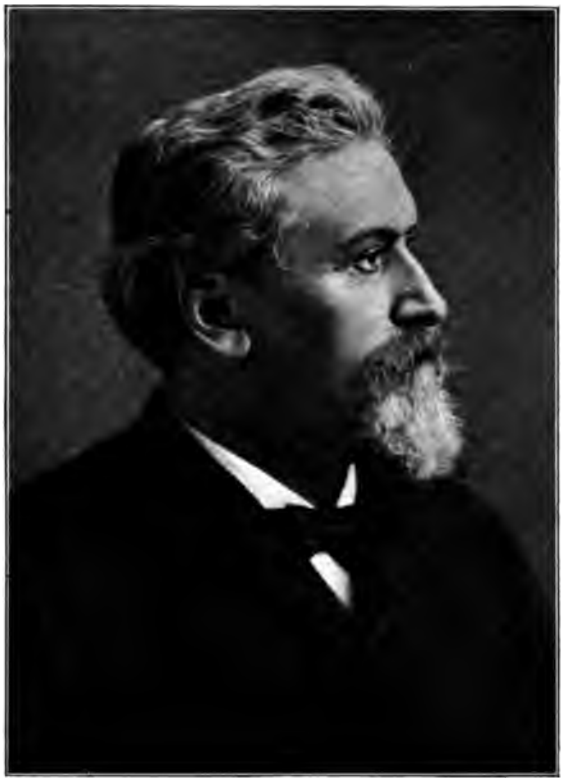
His first design on this plan was the bridge over the Monongahela River at Fairmont, W. Va., consisting of three spans of 205 feet each, built in 1852, this being then the longest iron railroad bridge span in this country.

The immediate cause of the invention of this truss was the desire to avoid building many masonry piers in a large river subject to sudden rises which would have greatly delayed the opening of the road for traffic, and the desire to secure an iron bridge with less material than the "Bollman" truss would have required for the same length of span.

The Fink truss is chiefly remarkable for its great simplicity. The strains in each member can be readily ascertained without intricate calculation, and

they are always either compressive or tensile, there being no member subjected to both these strains alternately, while proper provision is made so that no injurious effects are produced by expansion and contraction caused by changes in temperature or by variable loads.

The Monongahela Bridge was a through bridge with cast-iron chords and posts and wrought-iron tension rods, with pin connections throughout. The ends of the chords were hung by links upon pins in cast-iron towers, and the floor beams were hung by suspension links to the pins connecting the tension rods with the posts—thus allowing all parts of the truss to expand and contract without deranging the structure. Once properly erected no



ALBERT FINK, AGE 58.

subsequent adjustments were ever necessary on such a bridge. The plan was promptly adopted by Mr. Latrobe for all the bridges on the Baltimore and Ohio Railroad and the Parkersburg branch.

About the same time Albert Fink built two cast-iron high viaducts of novel design. They were erected upon a steep mountain grade and upon sharp curves, and were considered bold structures and were much admired.

All these works made a considerable reputation for him, and when the Baltimore and Ohio Railroad was completed he accepted the position of Resident Engineer on the construction of the Parkersburg branch, taking charge of the first seven miles from Grafton west. Mr. Latrobe was Chief Engineer,

and put him also in charge of the bridges and buildings. Here he made himself familiar with the use of the level and transit, and with graduation and masonry work, remaining from October, 1853, to August 1855, when he was appointed Division Engineer of the Western division of the same road, where he remained until its completion in 1857.

In July, 1857, Albert Fink went to the Louisville and Nashville Railroad as Assistant Engineer in charge of buildings and bridges—under George MacLeod, Chief Engineer. He was then in his thirtieth year and in the prime of life, with a capacity for work such as few men ever had. Though fully occupied with designs for the Louisville and Nashville Railroad he found time to prepare plans for rebuilding the Louisville Court House (in 1858) which were adopted, he being appointed to superintend their execution. In this work he displayed his talent and taste as an architect, and it added much to his reputation. The edifice is to-day the finest in the city, if not in the State, and the pride of the people of Louisville.

The Louisville and Nashville Railroad was opened through to Nashville in November, 1859. It was still very incomplete, it being estimated that nearly $1,000,000 was yet to be expended to make it a first-class road. In October, 1859, Mr. Fink was appointed Chief Engineer and Superintendent of the road and machinery departments. In 1861 the Civil War broke out, and there followed an experience in railroad operation, for four or five years, too dreadful, as we now think, ever to occur again. The line of road under Mr. Fink's charge ran directly through the region most affected by the contending armies in Kentucky and Tennessee, and was alternately in possession of the Confederate and Federal forces. The former first seized, in July, 1861, the forty-five miles of the road in Tennessee, with its rolling stock, and in September further took possession of all the southerly portions of the line to within thirty miles of Louisville, leaving but sixty-seven miles out of two hundred and sixty-eight which could be operated by the company. The Federal forces then advanced and the Confederates retreated southward, but while falling back they destroyed many of the bridges, either by burning them or blowing them up, burned the depots, the machine shops, the engine houses, and the water stations. They tore up many miles of track, piled up the ties and burned them after having placed the rails on top, so that the latter were badly bent, and carried off such of the rolling stock as was not in the ditch, so that the line was strewed with wrecks from one end to the other. Mr. Fink lost no time in waiting for the Federal forces to protect his workmen. He followed up the retreating Confederates with tireless energy, reconstructed the damaged portions of the road, trestled the bridges, built temporary water stations, straightened the rails and relaid the track, and picked up the wrecked engines and cars. This work was seriously interrupted by local freshets, which washed out some of the trestles, sometimes more than once, but, to the amazement of the military, these reconstructions were completed nearly as fast as the Federals advanced, and not infrequently ahead of them. So adequate was this reconstruction and the subsequent operation that the Louisville and Nashville was the only road in the South of which the Federal authorities did not take military possession, having realized that it could be repaired and operated by Mr. Fink more efficiently than by themselves.

The most extensive use of the Fink truss for bridge construction was for

the great bridge designed by him over the Ohio River at Louisville, which was built at this time, being opened for traffic February 12, 1870. There were twenty-three deck spans of the Fink type, of which the longest was 245 feet 6 inches, constructed entirely of iron, except the stringers, which were of white pine. The compression chords were formed of cast-iron tubes, octagonal on the outside, but circular inside, and connected with cast-iron sockets every second panel, which were turned and bored to a fit. The posts were of wrought iron, the largest of which was 13½ inches in diameter, and the bars were also of wrought iron.

More remarkable than these spans were the channel spans, which were of 370 feet and 400 feet span. The latter being at that time the longest truss span in America, and of a single intersection type, to which form bridge engineers are at last agreed upon after many years wandering in the wilderness. The main trussing is of the Warren type, of which there are seven triangles in the 400 feet span, of 56 feet 7¼-inch panel length. These are subdivided into four panels each, as shown in the diagram, forming a style of truss which has many points of superiority over the Baltimore truss, which is now in such general use, and is certainly no more economical nor so scientific. These channel spans were constructed of the same materials as the deck spans, the end posts being 17 inches in diameter and of the Phoenix type of column, with eight segments. Each span had four trusses, two on each side 41 inches apart, connected together with bolts and struts. The

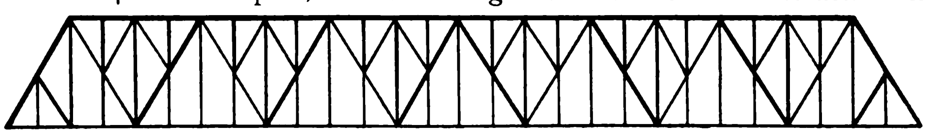


DIAGRAM OF 400 FEET CHANNEL SPAN.

workmanship was so exact that when the four trusses composing a span were swung, no perceptible difference in their camber could be observed. That the bridge is still in use, reflects great credit not alone upon the engineering skill displayed in its construction, but upon the types of trusses employed.

Mr. Fink's reports attracted such general interest among railroad men that copious extracts from the report of 1873-74 were reprinted for general circulation under the title of "Cost of Railroad Transportation." This was followed in 1874 by a treatise entitled "Investigation Into the Cost of Passenger Traffic," based upon the traffic of the Louisville and Nashville Railroad since 1867, which was to have been followed up by a second part containing the results of an investigation into the cost of freight traffic, the completion of which was prevented by Mr. Fink's official duties.

In 1875, Mr. Fink entered on the work for which, consciously and unconsciously, he had been preparing for years. It was a work of great originality, and of difficulties quite as great. A critical period in the history of the railroads of the United States had been reached, and, in the decade between 1870 and 1880, a very important change took place in the attitude of those who controlled railroad properties toward the owners of those properties, toward other railroads, toward society, and toward the State. In bringing about this change Mr. Fink had more to do than any other man, perhaps more than any other dozen men.

The Southern Railway and Steamship Association was organized in 1875.

LOUISVILLE BRIDGE, CHANNEL SPAN ON INDIANA END.

It was a combination of about twenty-five Southern railroads, formed for the purpose of controlling and regulating rates, to the end that they might be kept reasonably permanent and so controlled as to lead to the least possible discrimination between persons or places. It requires slight familiarity with the social economics of railroads to appreciate that such regulation of rates would sweep away most of the evils felt by the railroads themselves and by the communities which they served. The Southern Railway and Steamship Association was the first really important and influential combination of this kind, and one of the most successful ever established. Of this great organization Mr. Fink was the working chief, and all who are able to judge agree that its affairs were well managed from the start. The plan of work and the body of rules were prepared by Mr. Fink with German painstaking and thoroughness, and were administered by him with distinguished ability, justice, tact, and resolution.

In May, 1876, Mr. Fink felt that he could withdraw to resume his plan of rest and study, and after about a year spent in Louisville to arrange his personal affairs, he started in June, 1877, for a trip to Europe. This time he got as far as New York, arriving there at a time when the chief executive officers of the four eastern trunk lines were endeavoring to compass measures to prevent the recurrence of the disastrous railroad war of the preceding year. Mr. Fink was consulted, and so greatly impressed the executive officers that they prevailed upon him to organize and to conduct the affairs of their proposed association, upon a plan chiefly devised by himself. The Trunk Line Association which was then formed included the Baltimore and Ohio, the Pennsylvania Railroad, the Erie and the New York Central and Hudson River Railroad. It was established to divide the west-bound traffic. Late in 1878 these lines and their Western connections, north of the Ohio River, and east of the Mississippi River and to the Atlantic, and including also the Louisville and Nashville, agreed to co-operate in all matters relating to competitive traffic, and the Joint Executive Committee was formed. Of this Mr. Fink was made chairman, retaining also his commissionership of the Trunk Line Association. He thus became the executive officer of all the most powerful railroads in the United States, so far as concerned their competitive traffic arrangements. That he occupied a position of great power and great delicacy no one will deny. That he filled it with remarkable skill every one will admit.

Mr. Fink resigned in the middle of 1889, partly for the reason that Federal legislation nullified to some extent the effect of his labors and partly for the reason that his health was failing.

Mr. Fink was as far as possible from socialism. He believed in the free play of the forces that emperors or legislators cannot control, the forces which really make human progress. He always contended for the common law which embodies the wisdom and experience of past ages and which cannot be improved by special legislation; and Mr. Fink's labors if fully accepted would have made most special railroad legislation unnecessary, or would have so directed it that it would have been more efficient and beneficial. Thus he was a man whom Germany could ill spare, and whose teachings and example have helped to make our own Nation strong and free.

When, after this strenuous business life, the imperative need of rest came to him, Mr. Fink resigned the office of Trunk Line Commissioner, in 1889,

and went for a few months to Europe; thence returning with his only child, a daughter, to Louisville, Ky., he reopened the old home where he had spent the short period of his happy married life with Sarah Hunt. He kept it as a *reste à pied*, traveling extensively, both in this country and in Europe. Scenery was a source of great enjoyment to him, and he was interested in everything great and small, from the social problems of the places he visited to their local coloring and customs. While at home he occupied himself with his books, spending the better part of every day and far into the night reading with intense interest works on philosophy and history. In his retirement he missed greatly his active business life, but, although he had many tempting offers to return to it, he declined them all.

During the last two years of his life he had severe attacks of illness, caused by kidney trouble, each one sapping more his strength, both physical and mental, until his death, which came suddenly and without pain early in April, 1897.

Albert Fink's chief characteristics were conscientiousness, passionate love of truth, fine sense of justice, perseverance, untiring energy, dauntless courage, and strong will. Nothing could make him deviate from his path of duty. His strong analytical mind never rested until it had found the truth, the bed-rock of facts, and had discovered all the reasons why things were so and could not be otherwise. His decisions on questions submitted to him for arbitration were nearly always correct, and were readily accepted by both sides. His tenacity of purpose, his uncommon intellectual powers, and the power of concentration which he possessed to a remarkable degree, enabled him to solve intricate problems in fields of labor for which he had not prepared himself, and in which he had but little experience. As an energetic worker he had, perhaps, no equal among his contemporaries. Courageously and unswervingly he advanced to the goal he had set for himself in his early youth; to educate himself thoroughly, to develop his faculties to the widest extent and so rank with the highest in his profession. When he undertook work or study he gave all his energy to it, and he did it thoroughly. He was deeply versed in philosophy and history, and interested in science, literature, and art, and in touch with all the questions of the day.

Albert Fink was distinguished in appearance and unusually handsome. He was tall and well proportioned. He had a noble head and broad forehead. His mouth and chin showed the strength and force of his character, while the expression of his large, dark eyes was wise, calm, and thoughtful and infinitely tender. When he spoke, what he said was clear, concise, and to the point; in a very few words he told a great deal.

He enjoyed society, but his life was too busy for him often to be able to indulge in social pleasure. His manners were simple and very cordial. The strength and simplicity of his character and the kindness and gentleness of his nature won for him the affection of men and women, young and old. He had a strong and tender love for little children. In his tastes he was simple, and he spent little for his personal uses, but he was lavish in giving. No one ever called upon him in vain for assistance, and, without being called upon, he lightened the burdens of many who will remember him with grateful hearts. To be able to do good, to relieve suffering, was his principal happiness. He was a most remarkable man, a true gentleman, and one who had reached the highest type of humanity.

NOTABLE NEW BRIDGE SHOP MACHINES

THE equipment of the average bridge shop was not, a few years ago, of as advanced a type as was to be found in first class shops for the manufacture of other iron or steel work, and at the present time there are very many plants which are very far from having an economical power plant and outfit of tools. The steam was very often generated by an old type of boiler, carried a long distance by piping which was poorly protected and which had numerous right angle changes of direction, and then fed into or through an old "steam eating" plain slide valve engine. By a sometimes slippy belt the engine communicated motion to the line shaft, which was too often badly supported and out of line. The machines were belted from this, with an entire absence of economical arrangement of belts and pulleys. Yet to endeavor to present to the owners of such a plant a scheme for its proper operation was a thankless task and almost sure to be met with the reply that the amount of power used was so small as to render the matter of no consequence.

The amount of power required to drive the shafting in some of the best designed shops was a very large part of the total, requiring in one machine shop 80 per cent. of the whole, in several others on record, about 50 per cent, and in very few did it fall below 25 per cent. The amount in the great majority of bridge shops so used, and, it may be said, wasted, was never known, and the necessity for improvement never realized until the greater economy of electrical operation became noised about. That the amount to be saved was very much exaggerated by some of the electrical representatives was indeed fortunate, as this was the means of bringing electrical equipment into use in some places where otherwise it would have been very difficult to introduce it. The phenomenal development of electricity during the past few years has been rehearsed too many times to call for more than mention here, yet by its use for power in shops it has not only been a means of saving in the elimination of shafting, but the better boilers and engines required have been a marked improvement as well. The boilers used for electrical work are generally of a type which will furnish dry steam and which are saving of coal, the piping is most likely arranged by either the mechanical or electrical engineer, and where bends are required they are of large radius, while the engine to drive the dynamo is at least a well designed one with good speed regulation, and should be a high speed engine directly connected with the dynamo. The question as to whether each machine should have its own motor connected directly to it, or the machines grouped and several operated by one motor, through the medium of belts and countershafting, does not seem to be a debatable one—whatever is worth doing is worth doing well, even to the extent of separate motors for some very small machines.

The ease with which wires can be run to any part of a shop or to the yards, makes it possible to locate machines wherever it is best, and to use electric power for all the work about a shop. It has been customary for

some years to use motors to operate cranes and derricks, and now there are several hoists on the market so operated, designed to replace hand and air hoists.

The Armington (Fig. 1) is one of the latest of these, designed for hard, continuous service, with multi-polar dust and moisture proof motors. The controller, which is fireproof, is arranged to stop the motor automatically, making it impossible for the load to continue in motion, even if the operator should leave the hoist without stopping the motor. The hoist is made of steel throughout, only spur gears are used, and they are cut from the solid. With no differential or worm gearing, the load is sustained by an auto-

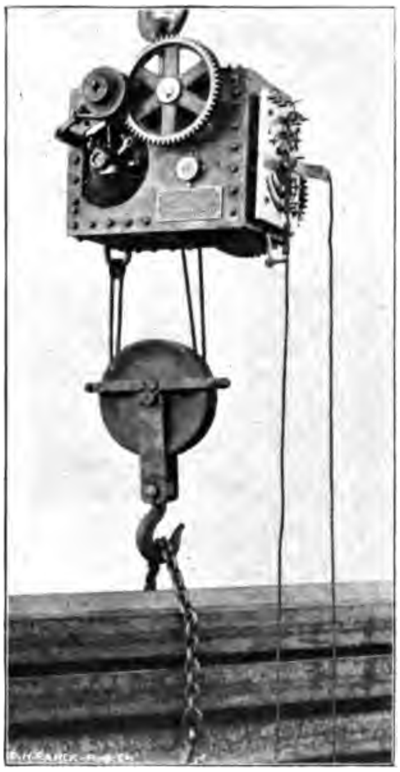


FIG. 1—ELECTRIC HOIST.

matic brake. By the use of an attachment in the block, two speeds are obtained, a direct lift of the hook being possible for a fast speed. They can be used with apparent ease for loads in excess of regular capacity, it being reported that fourteen-ton loads have been lifted with the ten-ton hoist. This being done with one man in place of four on a hand hoist, and in about one-fifth the time. The motors used are General Electric, the hoists being manufactured by the Cleveland Punch and Shear Works.

The use of a motor directly connected to a special beam and channel punch is shown in Fig. 2. The motor is fastened to a base casting which rests upon the floor, and which is connected firmly to the machine, making it easy of access for attention or repairs. The speed reduction is accom-

plished by two more spur gears than are usual on a punch, the fly wheel shaft being longer and bracketed from the punch frame to carry the cut gear which engages the one on the motor. The controller can be placed wherever it is most convenient, being unattached to the machine. The punch itself, which is a Hilles & Jones special No. 5, is somewhat remarkable in having a range for the outside punches of thirty-eight inches, it being possible to set them much further apart than is shown in the view and to add a large additional number in the sliding head, which is made of cast steel. The capacity is equal to punching two 1 1-16-inch holes through 1-inch thickness at one stroke. The main frame is of very neat design and of box form throughout, with the metal so distributed as to overcome any tendency to spring. The sliding head is counterbalanced through a spiral

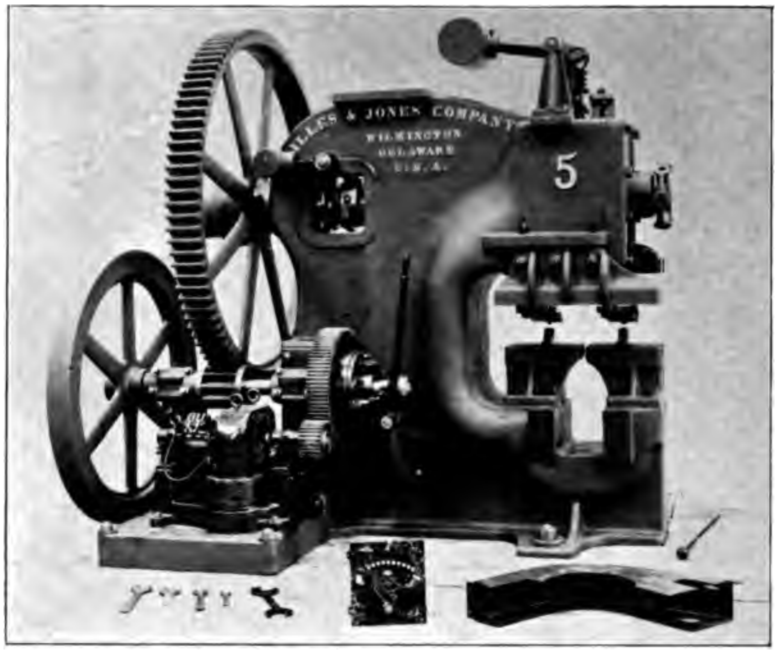


FIG. 2—MULTIPLE PUNCH.

spring and is provided with taper brass shoes to take up the wear. The punch is sometimes provided with a table and two carriages to enable the quick handling of plate work.

Another type of motor attached to a No. 7 multiple punch is shown in Fig. 3. The arrangement by which the motor is geared to the machine is exactly similar to that just described. The view shows a coping attachment substituted for the punches, which copes one flange at a time. The depth of the throat is twenty-two inches, with a capacity up to twenty-four inch beams, or as a multiple punch will punch fifteen $\frac{3}{4}$-inch holes through steel three-fourths of an inch thick at one stroke! The massive character of the machine can be appreciated from the weight of the main frame, which is eighteen tons!

The standard beam coping machine made by this firm, while not exactly

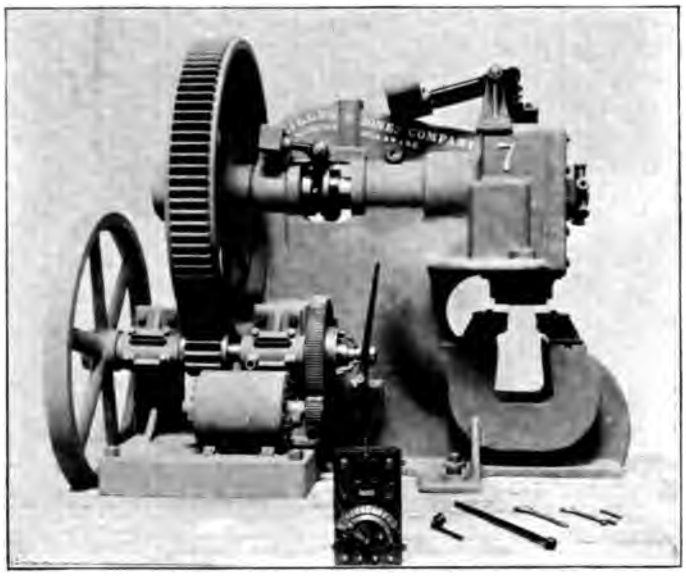


FIG. 3—COPING MACHINE.

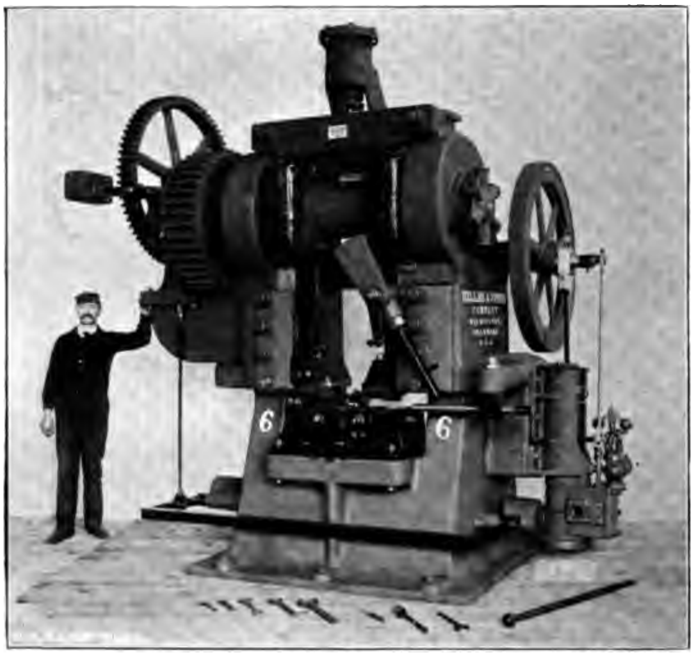


FIG. 4—HEAVY COPING MACHINE.

a bridge shop machine, being such as would be used by a steel mill, is such a notable machine as to deserve short mention. (Fig. 4.) While it is shown with an engine for driving it, a motor can be used. A beam can be passed entitrely through the sliding head, and the flanges coped or sheared for any length at any point. The flange can be cut away in this manner for the whole length of the beam on either side, or simply notched out for the clearance of another beam. There is also a separate pair of projecting blades which can be used for trimming off the web of a beam or channel after the flanges have been coped, thus making a beam to exactly the length required. The capacity of the machine is from 5-inch to 24-inch beams or channels.

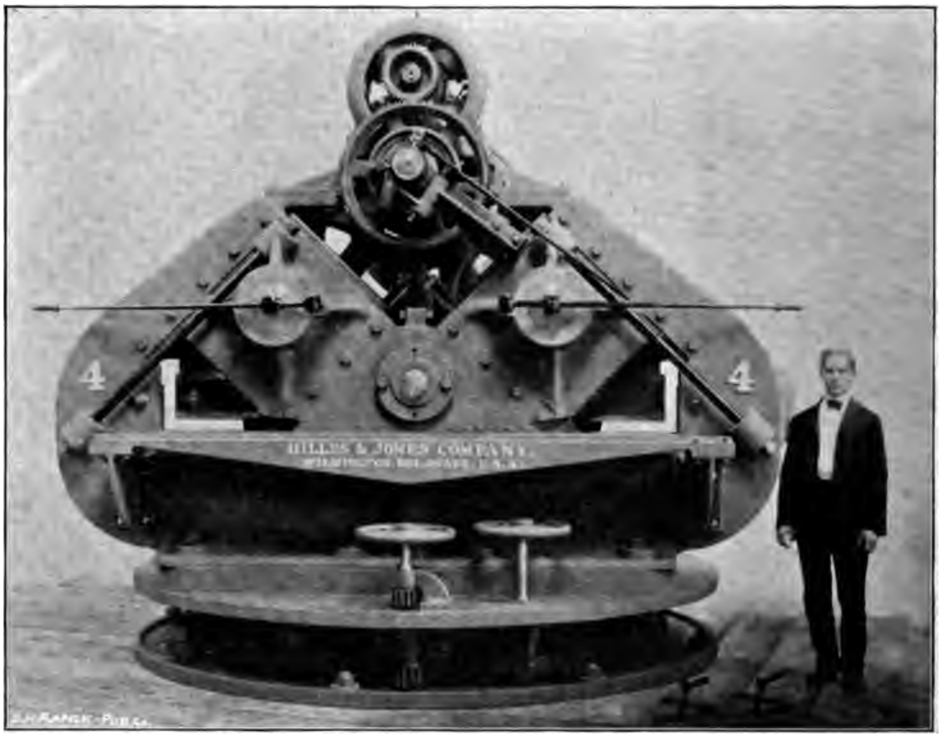


FIG. 5—ANGLE SHEARS.

The great length to which plate girder bridges have been built in recent years, from 90 to 125 feet, and the great increase in the train loads to be carried by them has brought into use very large sized angles, 8 by 6 and 8 by 8 being in quite common use and over one inch thick for very heavy work. In some shops it is the practice to punch them off and then plane the ends on a rotary; in other shops they are cut off by a cold saw, but where there are large numbers of big angles to cut to length, the old small sized angle shears are giving place to new ones of greater capacity. The one shown in Fig. 5 has a capacity for shearing 8 by 8 by 1 angles, without distorting the shape of the piece cut off, while a still larger size has a capacity for 8 by 8 by 1¼. The sliding heads, which are of cast steel, are operated

independently of each other, so that two gangs of men can be employed at the machine at the same time. The motor for driving it is, in this instance and of necessity, placed on top of the machine. The shear is mounted upon a turntable, ten feet in diameter, allowing it to be turned to any angle by the hand wheel at the left and clamped in position by the use of the right hand wheel.

The requirement in many of the leading specifications for bridge work,

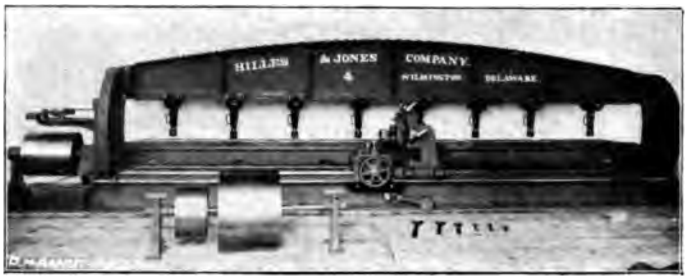


FIG. 6—PLATE EDGE PLANER.

that the sheared edges of steel plates shall be planed, has made it necessary for the larger shops to install a plate planing machine. The latest design is shown in Fig. 6, which has been built for a length of thirty-two feet, but the usual length is twenty feet, allowing a plate of this length to be planed at one setting. A built girder the whole length carries on the lower flange a number of jacks which are used to clamp the plates, it being possible to move them to any point by the trolley supports. The feed screw the entire

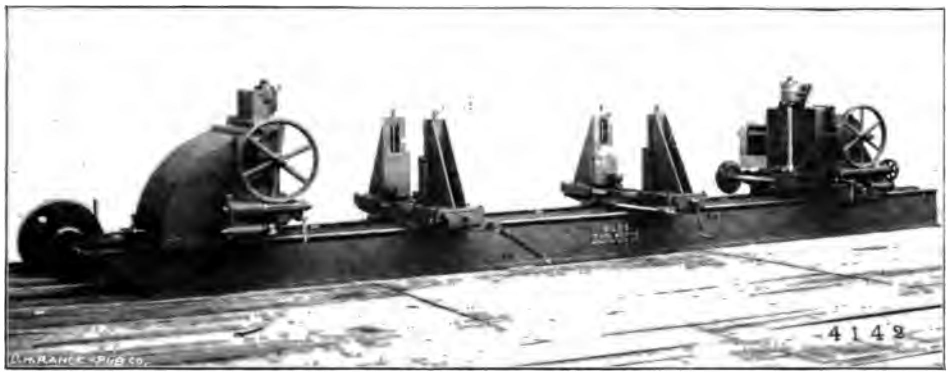


FIG. 7—DOUBLE COLUMN MILLING MACHINE.

length of the bed is provided with ball bearings to take up the thrust, and has increased the efficiency of the machine. The saddle, which carries three tools, is automatically shifted for the return cut in advance of the automatic shifting of the belts.

The rotary planer, which is utilized for facing the ends of compression members, is one of the most unsatisfactory machines that is used on bridge work, on account of the difficulty of making smooth cuts on the thin webs

and covers of a member. The spring of the plates causes the machine to jump, and before a great while the worm gearing becomes so worn that the machine hammers and attracts the attention of every visitor. Besides this, a rotary planer is not an economical type of machine. The success of milling machines in other kinds of work has led the Niles Tool Works Co. to place on the market a double column milling machine. The bed is composed of two girders strongly braced together, on which are the two cutting heads or columns of very solid construction. The machine shown in Fig. 7 will take in a member twenty-seven feet in length, one of the heads being adjustable for any length, so that both ends of a piece may be finished at once, and any number of the same length be made exact duplicates. If one end of a member, such as an end top chord or end post, is to be cut to a bevel, the stationary head can be tilted to the proper angle. The cutters stand in

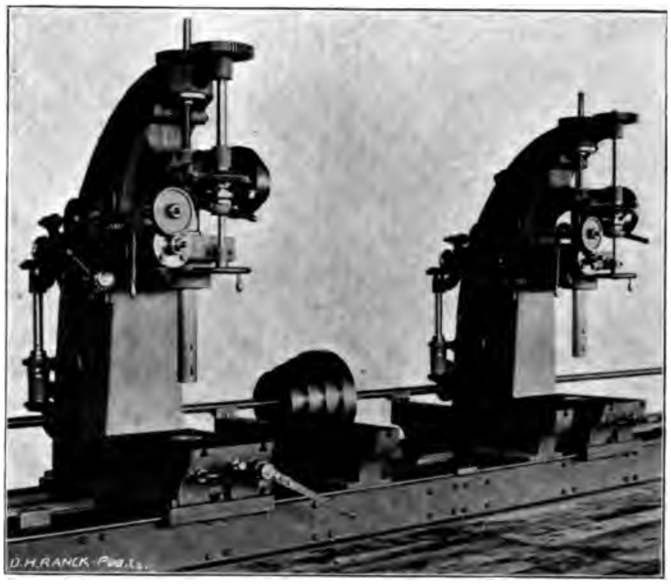


FIG. 8—DOUBLE CHORD DRILL.

a vertical position and have a cross travel of forty-two inches by means of a power feed. The work is held by two clamping carriages, which are regulated in position by right and left hand screws, the clamps being adjustable for various sized pieces. The movement of the adjustable head is accomplished with rack and pinion and a ratchet, besides which there is a fine screw adjustment for accurate setting. Even with the various improvements which have been made in rotary planers, allowing of accurate end adjustments of the cutter head and the setting of the machine at any angle, it would seem certain that milling machines with either single or double head, will supplant them.

The necessity for the accurate boring of posts and chords having two pin holes, besides the demand for machines which will cheapen the cost of work, has induced the same firm to build a double chord boring machine (Fig. 8). The two boring heads, or virtually separate drill presses, are

mounted on a bed similar to the one just described, and are adjustable for any length for which the bed may have been built. The machine illustrated has a reach of eighteen inches, and will take in work twenty-four inches high, while the capacity is for boring four eight-inch holes at one time, the holes being punched out beforehand to a diameter of four inches; each cutter bar holding two cutters, one for each web of a member. The work is supported by intermediate carriages, which can be provided in any required number to avoid deflection of a piece.

For drilling girder work from the solid, they have designed a multiple drill with eight spindles, with a capacity for drilling eight 1½-inch holes at one time (Fig. 9). Each spindle is counterweighted, with a vertical movement of twelve inches, while each one can be moved lengthwise to adjust the center distances, after which the whole eight can be moved simul-

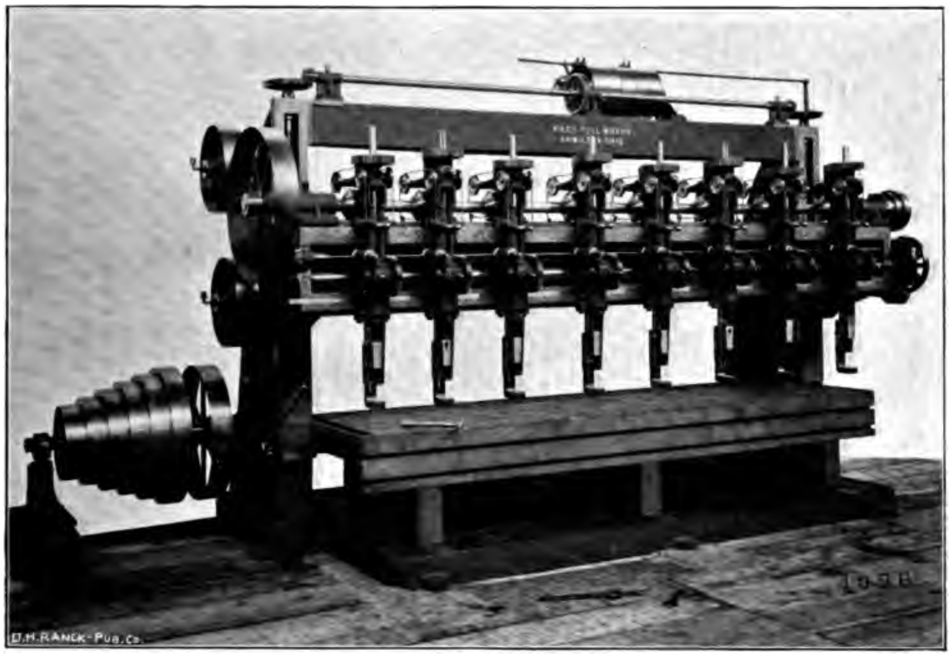


FIG. 9—MULTIPLE DRILLING MACHINE.

taneously to another nest of holes in the same line having the same multiple spacing. For example, the spindles may be set to twelve inches center to center, and by moving them six inches at a time, six-inch spacing may be reached, or by a three-inch movement three-inch spacing can be drilled. The machine will drill to the center of forty-eight inches, the table being forty-two inches wide and twenty-four inches above the floor, with a lateral adjustment of thirty inches.

Another machine for drilling girders is shown in Fig. 10, the drills being carried on a lattice girder which is hinged to the swinging arms, thus giving an endwise and parallel motion, the radius being seven feet. The arms are arranged for a vertical movement of five feet, being raised and lowered by power. The spindles, which can be increased in number, are driven by a

rope that passes the full length of the lattice girder, and after they are in position they can be clamped by the attachment on the arms. This machine is especially well adapted for reaming.

While the four machines last described are fitted for belts, they can be changed to use electric power and conform to what has been described for some of the heavier machines.

The power required for driving bridge shop machinery has never been determined for the varying conditions of practice, and there is a field open for extensive dynamometer tests; but it is certain that the power will never reach the popularly used figures, especially for well designed, modern machines. By a slight expense and by considerable trouble, it would be possible for ammeter records to be made, in a shop having each machine equipped with a separate motor, which would prove conclusively what power each machine consumed on different classes of work.

The fact, however, that most of the machines used on bridge work are very heavy and are used somewhat intermittently, is the main reason why separate motor equipment will be found economical. The average amount of power used will be smaller by a considerable percentage than the sum total of the power required to drive each machine separately.

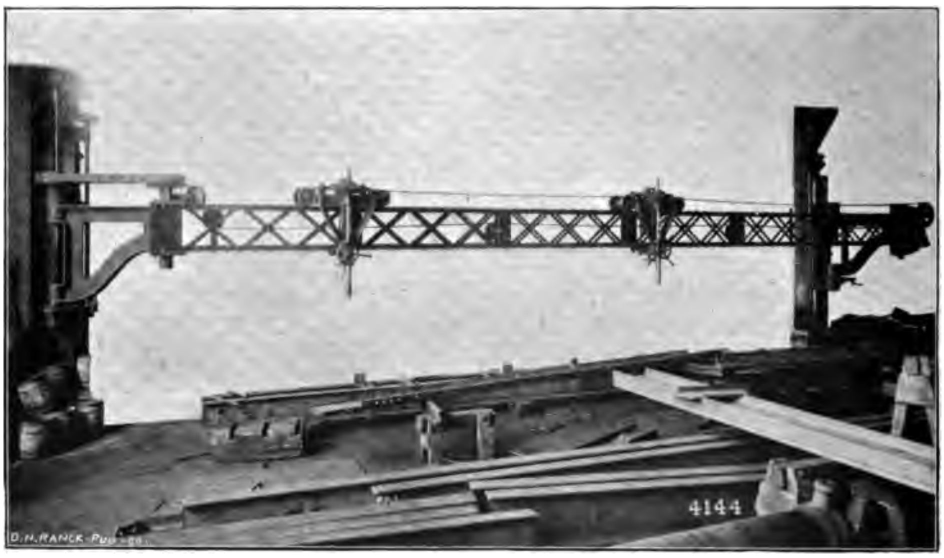


FIG. 10—GIRDER SWINGING DRILLS.

THE LOADING OF LONG STRUCTURAL MATERIAL

THE question of shipment is very often overlooked in the design of bridges and buildings, both by the purchasers and by the designing engineer. It is nearly always possible to so design a structure that the sections to be riveted up at the shops will comply with the regulations of the Master Car Builders' Association for the loading and carrying of long structural material, plates, rails, girders, and other metal work, especially if the designer has at hand the complete text of rules which are given in this article in their latest revised form.

GENERAL INSTRUCTIONS

1. On account of the great variety of form and weight of long structural material, no general rules can be made to suit all cases. The following regulations are, therefore, intended to cover only the most common forms. When material cannot be loaded in accordance with these regulations, special instructions must be asked for.

2. Cars to be used for shipments of this character must be carefully

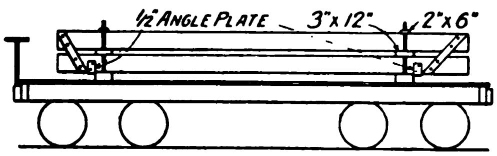


Fig. 1.

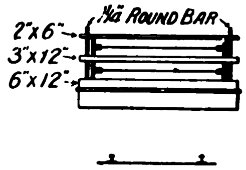


Fig. 2.

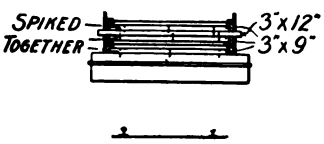


Fig 3.

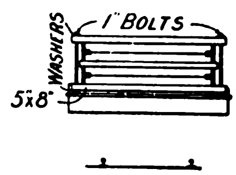


Fig. 4.

examined before loading, and all defects must be remedied before the cars are loaded. Great care must he taken not to overload cars, and in the case of very long or very heavy material, the trussrods should be screwed up tight. The weight of the lading carried on any car must be governed not only by the marked capacity of the car, but also by its general construction, as well as by the number and location of the bearing-pieces upon which the load rests. The regulations covering these points are given in the detailed instructions for each form of lading, and must be strictly adhered to. The only exceptions are for cars which have been specially prepared for the shipment of particular forms of material.

3. Material over forty feet long carried on two or three cars, must always be examined by a competent inspector before the cars are moved from the loading point. If an inspector is not stationed at the loading point, the agent must give notice to the proper authority when the cars

are loaded, so that proper inspection may be arranged for. The object of such inspection is to see that these regulations have been complied with.

3½. Cars intended to carry twin and triple loads, as per Figs. 10, 11, 12, 12-A, 12-B, 13, and 14, when weight of lading will equal half capacity of car or over, must have the bolster side bearings carefully examined before loading, in order that when loaded the trucks may curve freely.

4. All cars must be so loaded as to leave the brake accessible and operative. There must be a clearance of at least 4 inches between the brake wheel and the material; one brake for one or two cars, and two brakes for three cars.

When a single car is used the lading at the opposite end from the brake must not project beyond the end sill, except in the following case: When

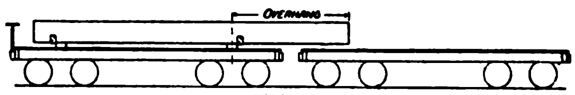


Fig 5.

the lading is too long to go inside the car, but will not extend more than six inches beyond the end sill, such method of loading will be permitted, providing the projecting ends of the material will clear 6 feet 6 inches above the rail.

When several cars are loaded with material requiring idlers, as in Figs. 5 and 6, there must not be any more of these cars close together in a train than that there will be one brake operative for one or two cars, and two brakes for three or five cars.

5. In all other cases where the lading extends beyond the end sills of the car, an idler must be used (which may be loaded as specified in paragraph 16), or the material must be loaded on two or three cars, as the case may demand, and as explained under detailed instructions below.

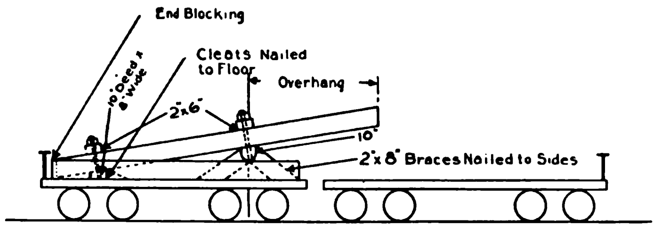


Fig. 6.

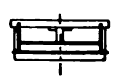


Fig. 7.

6. Long, iron, rails, bridge material, channels, angle iron, etc., should, whenever possible, be loaded on single gondola cars inside the end gates, which must in all cases be raised and securely fastened. Single flat cars must not be used for rails or bar iron, unless furnished with substantial end boards to prevent shifting of the load.

When plates are loaded on the floor of single high-side gondola cars, bearing-pieces must be placed on the floor to facilitate the removal of the lading. These bearing-pieces should be not less than 3 by 4 inches in section, extending the width of the car. There should be not less than two bearing-pieces to a car.

7. Whenever the lading is carried on more than one car, all slack

between cars must be removed by the use of spacing-blocks in the manner described in detailed instructions. Cars must also be chained together in order to prevent parting in case of failure of the couplings. When cars are used which are not permanently equipped with safety chains, chains made of not less than 3/4-inch iron must be passed around the body bolsters

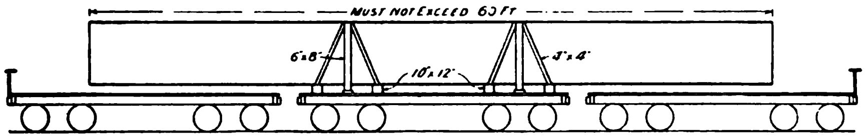


Fig 8.

and across under sills, forming a loop back of bolster and doubling to point of coupling between two cars, and so tie them together. These long chains must only have a sufficient amount of slack to permit the cars to curve. At interchange points the chains will either be removed, or the receiving road must furnish the delivering road with chains of the same quality and dimensions as those received.

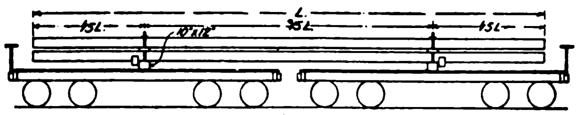


Fig. 9

8. Bearing-pieces must never be placed between the bolster and the end of the car, but either between the bolsters or directly above the bolsters. When only one bearing-piece is used on a car, as in Figs. 13 and 14, it must be placed at a distance of at least 12 inches from center of bolster toward center of car.

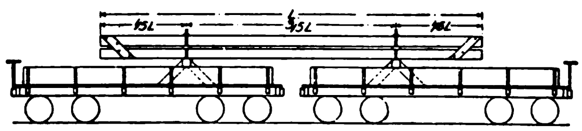


Fig 10.

Bearing-blocks which are placed flat on the floor of the car may be composed of built-up lumber, if securely nailed together to prevent displacement of the parts.

9. All spacing-blocks between cars, clamping-pieces, swinging bolsters, stakes, when over four feet high, and bearing-pieces located on top of sides

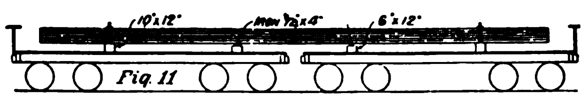


Fig. 11

of cars, with loads of half capacity and over, as in Figs. 6, 10, 12, and 12-A, must be of hardwood, and sound in every way. Bearing-pieces for twin loads, is in Fig. 9, if made of built-up lumber as described in paragraph 8, must have the top piece of hardwood. Dimensions are, however, intended to be general only, but represent the least allowable sizes which must be

used for loads exceeding one-half the capacity of the car. For lighter loads, the dimensions may be proportionately decreased, except where the size of timbers given is governed by the required clearance; however, any material that may be suitable for blocking which differs from the figures given, but which is of equal strength or stronger, may be utilized.

10. Height and width of lading must be governed by tunnel and bridge limits of roads over which lading is to pass.

11. When two or three cars are used, cars carrying load must be considered of the same capacity as the one of lesser capacity.

Detailed Instructions

LOADING OF SINGLE CARS WITHOUT IDLERS

12. Large girders, loaded on flat side on flat cars, must always be

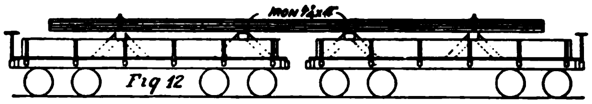


Fig 12

carried upon bearing blocks not less than 4 by 12 inches, which must be placed one over each bolster and secured to the floor with two 7/8-inch bolts. When two or more large girders are carried on a flat car, the bearing-blocks must be not less than 6 by 12 inches, and fastened in the same manner to the floor. In addition, spacing-blocks not less than 3 by 12 inches must be placed between each girder. Lateral motion must be prevented by means of upright iron stanchions, driven into holes in the bearing-pieces and held together at the top by not less than 2 by 6 inch planks, as shown in Fig. 2, or it may be prevented by fitting planks between flanges of the girders, as shown in Fig. 3. To prevent longitudinal motion, angle plates, 5 inches or six inches wide by 1/2-inch thick, must be bolted firmly to the lower girders close to the bearing-pieces, as shown in Fig. 1, or, if rivet

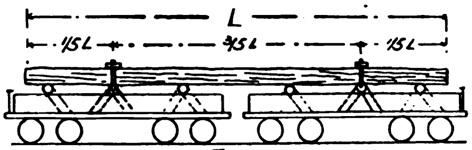


Fig. 12 A

holes are not available, it may be prevented by clamps, as shown in Fig. 4. The upper girder must be held to the lower girder by diagonal flat iron braces bolted to both girders, as shown in Fig. 1. If, however, girders are clamped together, as shown in Fig. 4, the diagonal flat iron braces need not be applied.

LOADING OF SINGLE CARS WITH IDLERS

13. When the lading is too long to go inside of a car, and extends more than 6 inches beyond the end sill, such loading will be permitted if an idler or idlers are provided to protect the overhanging part of the loads, as in Figs. 5, 6, and 8; but in these cases, the length of the permissible overhang must be governed by the width of the lading and its height above the rail, and it must in no case exceed the figures given below, which are based on clearance required on a 20-degree curve, is being under-

stood that the load must be placed centrally on the car, and the amount of overhang measured from center of bolster of the carrying car.

For loading in accordance with Figs, 5, 6, and 8:

8 feet wide.............................. 10 feet overhang.
7 feet wide.............................. 14 feet overhang.
6 feet wide or less...................... 18 feet overhang.

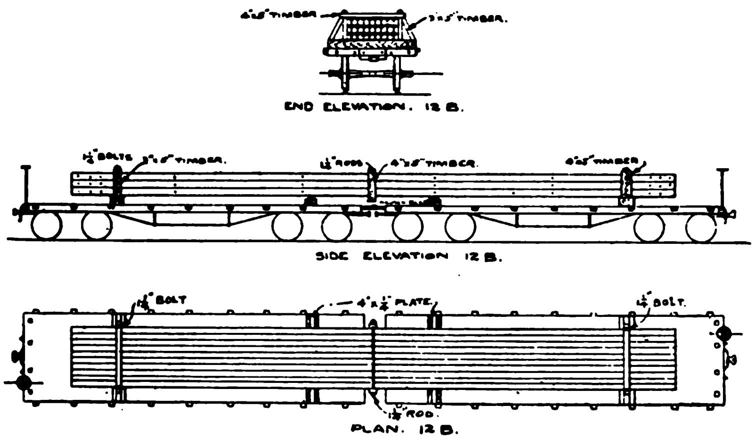
14. To prevent overloading of the truck under the overhanging end, as shown in Figs. 5 and 6, the carrying capacity of the car will decrease in the following manner as the length of the overhang increases:

For overhang not exceeding 5 feet, car my carry full marked capacity.

For overhang not exceeding 10 feet, car may carry three-fourths of the marked capacity.

For overhang greater than 10 feet, car may carry one-half the marked capacity.

However, should the overhanging material consist of a few pieces only, with a total weight not exceeding 2,000 pounds, the car may carry full marked capacity.



15. (*a*) The idlers used with loads, as shown in Figs. 5 and 8, must be flat cars, unless the width of the overhanging part of the lading is at least 3 feet less than the width given for each length of overhang in the table in paragraph 13, in which case drop-end gondola cars may be used.

(*b*) The idler used with loads as shown in Fig. 6 may be a low-side gondola car, but must not be a high-side gondola car.

16. The idlers may be loaded with any suitable material, provided the consignee and the destination of the material on all the cars are the same. There must be, however, a space of at least two feet between the ladings on the carrying car and on the idler. The carrying capacity of the idler depends upon how far the overhang extends over the idler, and must not exceed the following figures, except with ladings as in Fig. 6, in which the overhang may be so far above the floor of the idler as not to interfere with its lading. In such cases the idler may carry full marked capacity.

When overhang does not extend over the idler more than 5 feet, full marked capacity.

When the overhang does not extend over idler more than 10 feet, three-fourths of the marked capacity.

When overhang extends over idler more than 10 feet, one-half of the marked capacity.

17. When large girders are loaded, as shown in Fig. 5, they must be secured to carrying car as explained in paragraph 12.

18. When material is loaded on gondola cars and is longer than the body of the car, as shown in Fig. 6, one end must rest on a bearing-piece not less than 10 inches wide and of sufficient depth to prevent the lading at the end of car from touching floor. The bearing-piece to be placed

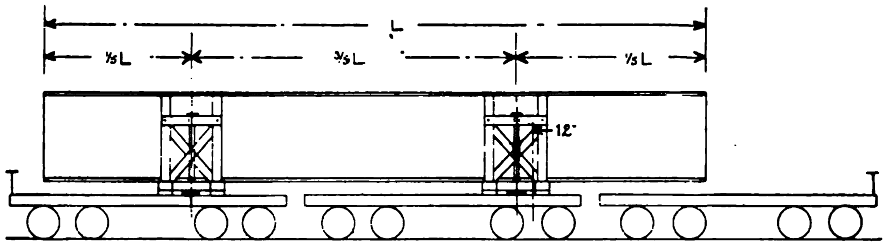


Fig. 13.

must be secured from shifting by cleats nailed to the floor. The end boards at this end of the car must be protected by blocking fitted between the side boards so as to prevent all parts of the load from injuring the end boards of the car. The thickness of the blocking may vary according to the weight of the lading, but should never consist of less than one 3-inch on the floor above the bolster and extending the width of the car, and plank set on edge for load of less than one-half capacity, nor less than two 3-inch planks or their equivalent for loads of more than one-half of the capacity of the car. If, however, the lading which butts against the

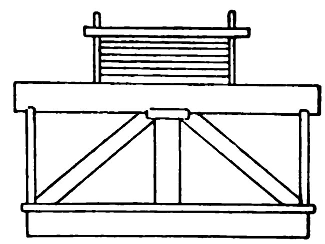


Fig. 13a.

end boards consists of only a single piece or two of a weight not exceeding a total of 6,000 pounds, no end blocking is required. When the lading consists of very flexible material, as plates, no bearing piece is required on the floor of the car, but blocking must be used to protect the end boards. The other end of the load must rest upon a bearing piece, square or round, preferably square, not less than 8 by 10 inches if square cornered, nor less than 10 inches in diameter if round, for loads of over half the capacity, and proportionately smaller to less weight of lading. This bearing piece must rest upon the side boards of the car, within one foot on either side of the center, above the bolster, and must have the ends notched for the

side boards and be securely braced, to prevent both lateral and longitudinal motion, as well as bending and rolling. Figs. 6 and 7 show substantially how both bearing pieces are to be secured. If the overhanging material is very flexible and interferes with the end boards of the adjacent car, a suitable bearing piece, protected by a strip of iron, must be placed on the adjacent car to support the material. To prevent the load from shifting in a lateral direction on the bearing-pieces, iron stanchions, tied together at their upper ends, must be used on both bearing-pieces, as described in paragraph 12.

19. A method of loading especially adapted to long lattice girders, which may be injured if loaded on more than one car, is shown in Fig. 8. For loads of this character, four bearing pieces must be placed in pairs on the carrying car, each pair being placed centrally above the bolster, with a distance apart of not over 5 feet nor less than 3 feet; they must be fastened to the floor with bolts, as explained in paragraph 12, and the upright supports must have side braces. Braces or tie-rods must be secured to the overhanging ends and to the bearing pieces, as shown in Fig. 17. Longitudinal motion must be prevented by the use of plates or clamps, as explained in paragraph 12.

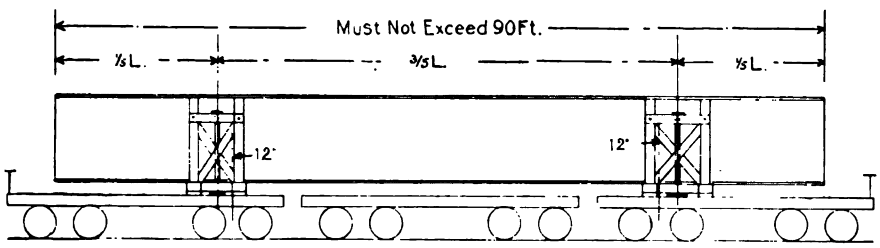


Fig. 14.

LOADING OF TWO OR THREE CARS WITH OR WITHOUT IDLERS.

20. Material which in length exceeds the limits given for the loading of one car must be loaded on two or three cars, as shown in Figs. 9, 10, 11, 12, 12-A, 12-B, 13, and 14. With loads of this character, the lading must never exceed the maximums given in paragraph 26, the carrying cars must always have all slack between them removed by the use of spacing-blocks, as described in detail in paragraph 28, and the cars must be chained together, as explained in the general instructions, paragraph 7.

21. Material loaded on gondola cars with drop ends or open ends, or on flat cars, as shown in Fig. 9, must have one bearing piece not less than 10 inches wide by 12 inches deep secured to the floor of each car with two 7/8-inch bolts. Lateral and longitudinal motions must be prevented in the manner described in paragraph 12. In the case of gondola cars, a clearance of at least 18 inches between the load and car sides must always be provided for curving. The clearance must be measured at the narrowest part of the car.

22. Material loaded on gondola cars without drop ends, as shown in Figs. 10 and 12, must have bearing pieces placed on the top of the side boards, of the same size and secured in the same manner as described in paragraph 18. The lading must be secured from lateral and longitudinal motion as described in paragraph 12.

23. Long, flexible material, like plates, etc., which cannot be loaded as shown in Fig. 6, must be loaded on four or more bearing-pieces, as shown in Figs. 11, 12, and 12-A. If loaded on four bearing pieces, as in Figs. 11 and 12, the two center bearing pieces must be 4 inches lower than the end pieces and have flat iron ¼ inch by 4 inches secured to their upper sides, either with spikes or lag screws at each end. These iron pieces, which are intended to facilitate curving, must extend at least 16 inches beyond each side of the lading, AND MUST BE COATED WITH GREASE BEFORE THE LADING IS PLACED UPON THEM. The bearing pieces must be secured to the car and the material clamped together to prevent it from shifting, in the manner described in paragraphs 12 and 18. The bearing pieces at each end of the load are the only ones to be provided with stanchions. When the bearing pieces are located near the center of the cars, as is the case

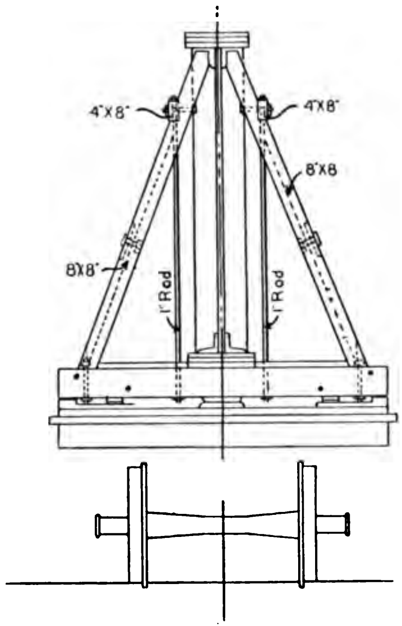


Fig. 14a.

with the end pieces in Fig. 12, and when the load so carried is equal to one-half of the capacity or over, the bearing pieces must be secured with lateral bracing pieces, as shown in Fig. 13-A, to prevent the breaking down of the sides when going around curves. When material is loaded on four bearing pieces on gondola cars with drop ends, the same clearance must be provided between the lading and the car sides as specified in paragraph 21. If more than four bearing pieces are required to properly support the lading, the center pieces only on each car must be provided with upright stanchions, as described in paragraph 12 and as shown in Fig. 12-A, all other bearing pieces to have flat iron secured to their upper sides to allow for curving, as provided for above. The spacing of the bearing pieces on the cars must be so arranged that the distance between the two center bearing pieces is about three-fifths of the total length of the lading, and the over-

hangs at each end one-fifth of the lading, as shown in Fig. 12-A. For loads of this kind the over hang is measured from the center bearing pieces to the end of the material, and must not exceed in length the figures specified in paragraph 13, for the respective width of the load. If, in order to make up the allowable carrying capacity of the cars, short material is loaded on the floor, with loads as per Figs. 10, 12 and 12-A, such material must be loaded in equal amounts on both sides of the car, so as to be properly balanced and not interfere with the curving of the trucks.

"T" and girder rails 60 to 65 feet long may be loaded on four bearing pieces, if desired. When so loaded the height of the center bearing pieces must be governed according to the flexibility of the material, as follows:

For material less than six inches, center bearing pieces to be four inches lower than end pieces.

For material six inches or over, center bearing pieces to be two inches lower than end pieces.

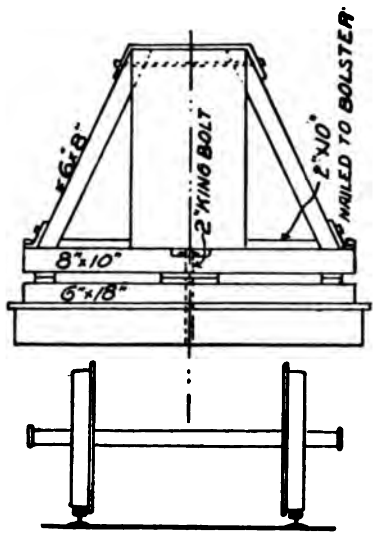


Fig. 15.

Flat iron must be placed on center bearings, and other conditions to be followed described above, and as shown by Fig. 12-B.

24. Large girders loaded on edge, as shown in Figs. 13 and 14, on two or three cars, either with or without idler, must be supported on two swiveling bolsters. The construction of the bolster should be governed according to the shape or weight of the girders.

Thus, girders fifty feet long and over and eight feet high and over should invariably rest on crib bolsters firmly bolted together, and to have double upright braces on each side, as shown in Figs. 13, 14 and 14-A.

Girders which do not exceed the above dimensions do not require crib bolsters, but may be supported on single bearing pieces, with one upright brace on each side of bolster, as shown in Figs. 15 and 16.

When loading girders which exceed in weight one-half the marked capacity of the cars, and when the location of the bearing pieces is over three feet away from either cross bearers or car bolsters, the car floor should be

reinforced by bearing pieces immediately underneath the bolsters, as shown in Fig. 15. These bearing pieces must be securely fastened to car floor, as described in paragraph 12, and must be not less than six inches deep by eighteen inches wide.

King bolts, center bearings and side bearings must be used for either kind of bolster, and both center bearings and side bearings for the upper bolster must move on corresponding bearings, secured either to the lower bolster or to the floor of the car, as the case may be. When wrought-iron plates are used for side bearings the lower plate must be fastened to the car floor with countersunk screws, or with two lag screws at each end, placed at least twelve inches away from sides of bolsters.

Girders which are not loaded on crib bolsters must be secured to the upper bolster with diagonal tie-rods or braces, as shown in Fig. 17. If braces are used they must be not less than 3 by 8 inches. The diagonal side braces between the top flange of the girder and the outer ends of the bolster must be secured in either of the methods shown in Figs. 14-A, 15 and 16. When the lading consists of two or more girders standing side by

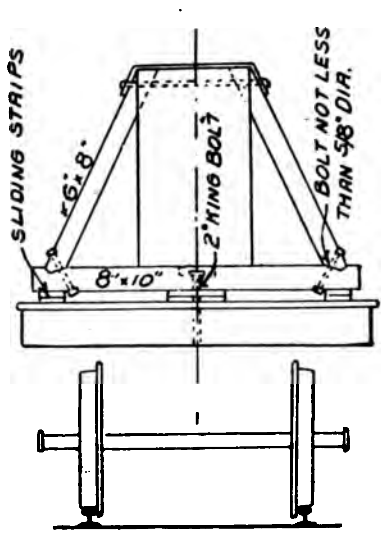


Fig 16.

side or lying on their sides, they must be securely fastened to each other, as described in paragraph 12.

25. The location of the bolsters depends upon the length and the width of the girders, as well as upon their stability, and they should, if possible, be so placed that the length of each overhanging end is not more than one-fifth and the distance between the bolsters not less than three-fifths, of the total length of the girder. The following table gives locations of bolsters for girders of maximum length and width based on clearance required on a twenty-degree curve:

60 feet long by 8 feet wide or less, bolsters not less than 36 feet between centers.

70 feet long by $7\frac{1}{4}$ feet wide or less, bolsters not less than 42 feet between centers.

80 feet long by 6½ feet wide or less, bolsters not less than 48 feet between centers.

90 feet long by 5½ feet wide or less, bolsters not less than 54 feet between centers.

In cases of material of less width than 5½ feet but of greater length than 90 feet, application must be made to the proper authority for special instructions.

26. To prevent overloading, the following regulations must be adhered to:

(*a.*) For loads carried on one bearing piece per car located near the center of car, as in Fig. 9: On flat cars having only two truss rods the weight of lading must not exceed one-half of the marked capacity of car. On flat cars having more than two truss rods, and on low-sided gondola cars, the weight of lading must not exceed two-thirds of the marked capacity of car.

(*b.*) For loads carried on one bearing piece per car located about equal distance from center of car and center of truck, as on end car in Fig. 13: On flat cars having only two truss rods the weight of lading must not exceed two-thirds of the marked capacity of car. On flat cars having more than

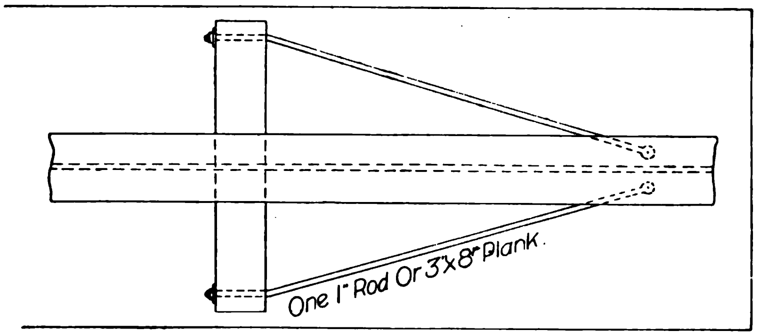


Fig. 17.

two truss rods, and on low-sided gondola cars, the weight of lading must not exceed three-fourths of the marked capacity of car.

(*c.*) For loads carried on one bearing piece per car located at or near center of the truck, as on center car in Fig. 13, and on end cars as in Fig. 14, or on top sides of high-sided gondola cars as in Fig. 10, the weight of lading must not exceed one-half of the marked capacity of car.

(*d.*) For loads of long flexible material carried on two bearing pieces on each car, as in Figs. 11 and 12, the weight of the lading must not exceed three-fourths of the marked capacity of the car.

For "T" and girder rails 60 to 65 feet long loaded on flat cars, or on gondola cars with drop ends, in accordance with paragraph 23 and Fig. 12-B, the weight of the lading may be equal to the marked capacity of the car. For loads carried on three bearing pieces on each car, as in Fig. 12-A, the weight of the load so carried must not exceed one-half of the marked capacity of the car, but short material may be carried in addition on the floor of the cars, providing the total weight of the load does not exceed three-fourths of the marked capacity of each car.

Among the twenty-nine problems which have been remitted to the sub-commission for further study and report, by the Stockholm Congress, are three which are of special interest to sidero-metallurgists, and are at the same time of considerable commercial interest. Before mentioning these in detail, I desire to explain that it had become apparent to European engineers that there were other fields in which the association could profitably work, besides the more abstract or strictly technical subjects of methods, standards, etc., etc., which had theretofore occupied its entire attention. Moreover, the result achieved had been so satisfactory and the recommendations had been so generally adopted, that it seemed possible to make the deliberations of immediate practical value.

It had been felt that the u e of materials for specific purposes was so heterogeneous and indiscriminate, and the specifications under which they were to be made and inspected, so manifold, in many ways original, and showing the idiosyncrasies of individual engineers and corporations, that it was deemed the proper time to take up these subjects with the view of introducing system and method into this apparent chaos.

For this purpose, and with this in view, the following problems were proposed and have now been submitted to commissions for consideration, investigation, and report:

(1) On the basis of existing specifications, ways and means are to be suggested for introducing international rules for testing and inspecting materials.

(2) Proposition to determine methods of determining the homogeneity of iron and steel, applicable for purposes of and at the time of inspection.

(3) Collection of information for the purposes of establishing standard piece-tests for the purpose of properly and rapidly inspecting lots of finished material, such as rails, axles, ties, springs, cast and wrought pipes, and other finished parts of structures.

The chaos of specifications for material had already necessitated the arrangement of all iron materials into groups or classes, and this, as the processes of making the materials were few and very similar, did not offer many difficulties. The processes used in other countries had not been considered, as there was no person present interested in them, to present their differences and suggest the advisability of broadening the field of study so as to cover all processes used in any country. As the English had never taken any part in these deliberations, they had not become cognizant of the peculiarities of their own requirements and specifications, and have not even adopted approximately uniform methods of tests and shapes and sizes of test-pieces, so that at the present time an English report of tests is the least valuable of any, because not made on a basis and standard, well known and clearly understood in every case, without special inquiry.

The first of the problems stated, now before the International Society, shows clearly that it is generally recognized that there is a multitude of varying specifications and rules for testing and inspecting materials, and that it is considered advisable to introduce some sort of uniformity. The object is, of course, to facilitate labors of the works and of the engineers, as well as to open the way to a clear understanding by all parties interested, of the intents and purposes of the specifications and their proper interpretation. Nothing is more annoying to the manufacturer and the user than misunderstandings in regard to the intent and meaning of some part of the contract after the same has been signed. Unfortunately, these details of contracts are rarely discussed in advance; and, in fact, in most cases this would not be possible, because it is common practice to contract to furnish a lot of steel by the hundred or thousand tons for "structural purposes, rails, ship-plates, etc.," without any statements as to quality, because it is assumed that this is a matter for easy later adjustment. When the time for the latter arrives—if, indeed, it is not left until the material is actually ready for delivery—then the trouble begins. If, however, a set of standard specifications were formulated, the difficulties would readily be eliminated, if prepared on a sufficiently broad basis, because the basis at least would in every case be well known.

At the present time it is recognized that there is such a general exchange of material between distant countries that it no longer suffices to prepare specifications which will answer either for Europe or for the United States alone.

The United States buy steel and iron in large quantities from Sweden, England, and

Germany. On the other hand, the same countries buy larger and larger quantities of materials from the United States.

However, the materials made in the United States are made from different crude materials and by methods different from those used in other countries, and while the chemical compositions vary considerably, actual use of them on a larger scale and experience under most varying and trying conditions have demonstrated their uniformly good and satisfactory qualities. Hence, while we know that American materials answer every purpose, they do not apparently comply with foreign specifications. Here the American national character has again made itself felt, and in a most pronounced manner. It was found that our materials would produce a finished product which is not that fulfilling old specifications; nevertheless, it was tried, and in a short time was found to be satisfactory for many purposes and in many ways. This gave encouragement to use it on a larger scale, with similarly satisfactory results.

These results of practical experience were laid before American engineers, and specifications were at once modified to suit these new conditions, replacing the old by something better. In Europe this would be a very difficult and tedious procedure. If Americans desire to make any impression on conservative elements, we must submit all our facts and evidence in such manner and by such responsible and trustworthy individuals or organizations, that credence will be given them wherever presented.

We now know that our materials answer every purpose, and, although containing what were formerly considered impurities (and are now known to be almost necessary admixtures), in this respect failing to meet some American and nearly all European specifications, fully comply with the requirements of actual use, and hence should be permissible in best construction.

It now depends upon proper and authoritative demonstration and elucidation of these facts, by careful collation of practical experience and tests under the direction of such reputable and well-known institutions as the Franklin Institute of Philadelphia, to take up the subject in order to be able to present overwhelming array of facts obtained from practical experience, sifted and arranged in proper manner, with documentary evidence.

Such array of proofs presented to the International Association for Testing Materials would at once reach all of the authorities interested in the subject, and would accentuate the necessity for revision of specifications for material with a proper regard to actual advanced conditions of the American steel industry.

It seems to me that no one would find a more prompt response in regard to collecting sets of specifications and reports of experience with material than the Franklin Institute. Hence it would, in my opinion, be a wise move for the Institute to enter upon a field of activity in which it would render immediate practical service in the interest of our most prominent industries. Coöperation of the Franklin Institute with the International Association for Testing Materials would no doubt advance the interests of both and lead to results practically valuable; it lies directly in the sphere of action laid down in the charter, and will have a far-reaching and beneficial effect in Pennsylvania, which is so largely dependent for its welfare upon the advancement and success of its metallurgical establishments, than which there are no more important in the world.—*Gus. C. Henning, in Journal of Franklin Institute.*

OCEAN FREIGHT RATES AND ARGENTINE TRADE

The Department of State has received the following, dated Buenos Ayres, from Minister Buchanan:

My observation leads me to feel sure that many low-priced staples used in quantities here come from Great Britain and not from us, wholly because of the difference in freight rates between the two countries and this.

It is to be remembered that there are numbers of ships sailing between here and England and the Continent, and that the larger part of the traffic is from this country outward. This being true, it is easily seen that rates from England or the Continent to this country are more tractable and amenable to negotiation than are those from New York, where there are few ships engaged in the trade, and those owned and operated, with one exception, by companies having the bulk of their fleets engaged in the traffic between this country and England or the Continent.

Until this phase of the question is carefully studied, one fails to realize the great influence on our staple trade by our dependence upon foreign shipping interests.

For instance, a barrel of lubricating oil costs in New York $3.12. The freight hither is $2.64. and the duty $5.10 in Argentine gold. Is it not remarkable, under such conditions, that we have as large a trade here as we have? Again, a barrel of gas oil costs in New York $2.62½. The freight is $2.64; the duty nothing. Under such a freight rate, it is easily seen that a difference of only 5 or 10 cents a barrel would be sufficient to turn the trade from us to any country where the cost price of the article was the same as our own.

I am convinced that we should give this subject special attention, as I am sure that orders for staple goods, especially for machinery and steel products, have gone, and will continue to go, to England and Europe, not because the goods can be purchased cheaper there than in the United States, but because the advantages our country offers in the original cost of such goods are more than offset by the difference existing against us in the freight rates from New York to this city and those from English or European ports.

For instance, I know of one shipment from England of an 11-ton boiler in pieces. The freight thereon was £11 10s.—or, say, $55 in United States gold, or $5 per ton. The same importing firm received from the United States a 33-ton boiler of the same kind as the other, and in pieces. The freight thereon was $750 in United States gold, or $23 per ton, a difference of $18 gold per ton in favor of the English manufacture. The freight on the shipment from England was calculated by weight, while that on the shipment from the United States was computed by measurement.

These importers tell me that they can buy such boilers and much heavy machinery and steel products very much cheaper in the United States than they can in England, but that they are obliged to buy them in the latter market, because the difference against us in freight is so great that it much more than offsets the difference in our favor on the first cost.

Without citing, as I could, other specific cases, let me say that the statement has been made to me by many importers here that the three lines operating ships between New York and the River Plata maintain at New York a close freight-rate understanding, and that the arbitrary and stiff rates thus held in force for River Plata freight undoubtedly injures our trade with these countries in many instances, and will continue to do so.

The reasons underlying this condition of things are, I think, apparent to anyone who has given the subject any consideration. Briefly, they appear to be the following:

First—That the great bulk of all River Plata products find their market in Great Britain or Europe, and hence shipping from those countries finds "return cargo." When there are large quantities of wheat, wool, and cattle to be moved, competition in rates to this country is certain, between companies engaged in operating ships between here and the Old World. On the other hand, when the crops fail here, rates to this country advance, because of the consequent lack of "return cargo."

During the past two years, and largely as a result of our tariff on wool, our purchases here have notably decreased in volume, whereas our shipments hither have increased, so that now there is nothing like sufficient return cargo for all the ships reaching here from New York. As a result, such ships either load to Rio de Janiero with cattle, picking up here such through New York freight as they can find, and then completing their load with coffee, or they go in ballast to a Brazilian port, where they can find a cargo for New York or Boston.

It is therefore plain why freight rates from New York are arbitrary, high, and unelastic, and why they will probably remain so.

Second—With possibly one exception, all the steamship companies plying between the United States and this country maintain the larger portion of their ships in the traffic existing between England and here. They are therefore able not only to maintain stiff outward rates from New York by means of such an understanding as they are said to have, but also to manipulate their ships as the demands of outgoing Argentine traffic may make necessary, or as may seem desirable from their point of view.

The remedy for this state of things is not easy to point out. It must, however, soon be found by our people, since it is not to be

supposed that we will allow our trade with these countries and with others to be jeopardized and held in check by our lack of capacity to grapple with and solve the chief difficulty in our path, as well as one of the most important problems we have before us as a people—the creation and rapid building up of a United States merchant marine.

THE NATURAL WIDTH OF RIVER CHANNELS

An article which we published in June last drew attention to a most important question which has hitherto been left too much to the arbitrary decision of personal experience. The extent to which the width of any river may safely be contracted by a bridge or other work is in most cases still determined by a visit from the consulting or chief engineer, who, having placed his head the least bit on one side, sees suddenly the fit and proper width.

The figure fixed upon of course represents the net result of his experience, but even if an individual could boast as much of knowledge as the world has known, it would be far more accurate and safe if that consulting engineer would formulate the process by which unconsciously he reached that same conclusion. The problem is one which admits exact expression, and there is much suggestiveness in the short note which our contributor devoted to the subject, though on a minor point or two we take exception to his methods.

It is asserted in the article referred to that normal depth in any stream is wholly independent of discharge. and this is proved as as follows: The mean velocity $= \sqrt{\frac{2gR}{Lm}}$ where L is cosine surface slope, R is the mean hydraulic depth, and m a constant depending solely on the substance forming the river's bed. This could not really be strictly true, since coefficient of velocity does not alone depend upon the bed, but we may safely let this pass. It certainly depends upon the bed more than on any other factor, and for our purpose may be taken as constant for a constant slope and earth. Our author then proceeds to argue that sinse kinetic energy is as the square of this velocity, or as $\frac{2gR}{Lm}$, and since both slope and bed are constant, this R, or depth, is always constant also!

The object simply is to prove that depth is independent of discharge, and to achieve this simplified result we calmly leave discharge entirely out! *Vis viva,* or kinetic energy, is v^2 multiplied by *mass;* this is, of course, not constant while the discharge varies.

The case does not admit of quite such simple treatment. In the first place, the flow in any stream should be divided into portions—those by the sides and that which forms the center. It is far easier to analyze the center than the sides, and since these latter sections form but a small portion of the whole in all the cases we consider now, and since the side widths vary far more slowly than does the central breadth, we may, as an approximation, only think of this central rectangle alone.

The whole potential energy in any uniformly flowing river, lost in a fall through any height, is lost, as heat produced by friction. This friction is made up partly of friction with the bed, partly of fluid friction. The former is, *instrinsically,* far the greater, and must make up in every column section for the deficiency in fluid friction. Therefore, there is a certain depth on any given bed and slope when this required friction can just be balanced by the bed's resistance. So much of truth lies in the given statement, but it by no means follows all rivers with like beds and slopes have the same depth. This holds alone for steep slope channels entirely unrestricted at the sides. Reduce the discharge of the Mississippi to one-half, and, though reduced it flow a hundred years, it never will be quite as deep as now.

Pending the full and accurate solution, there is a good and safe guide close at hand. That is, the greatest normal depth existing in the neighborhood. Discard anv extraordinary and deep hole, if such there be, scoured by unusual peculiar features, take then the greatest depth elsewhere as that which shall exist between your piers, and—granted that your training works will stand—your bridge will be both economical and safe.—*Indian Engineering.*

THE NEW BRIDGE AT DUSSELDORF

Nearly two years ago there was given in these columns an account of the plans for the new bridge across the Rhine at Düsseldorf, and the peculiar conditions under which

the work was undertaken were then stated at length. The completion of this important engineering work is now the occasion for several articles in the technical press, and from illustrated descriptions in the *Zeitschrift des Vereines Deutscher Ingenieure* and the *Oesterr. Monatsschrift fur den Oeffentlichen Baudienst* some interesting features of the bridge are obtained.

In brief, the bridge has been constructed by a private corporation, and, in consideration of this construction, there has been granted to the company the right for an electric railway from the center of the city, across the bridge, to Crefeld, some thirteen miles away, together with the collection of tolls on the bridge, and a title to more than nine hundred acres of reclaimed land on the left bank of the Rhine.

The total cost of the bridge, not including approaches and land damages, was 3,800,000 marks, or, including these additional charges, as well as interest, about 6,000,000 marks. As an engineering work the Düsseldorf bridge reflects great credit upon Professor Krohn, by whom the design and computations were made, and also upon the Gutehoffnungshütte, of Oberhausen, by whom the structural work was done and the erection conducted.—*Eng. Magazine.*

STEEL FRAME CONSTRUCTION FOR DWELLINGS

Our readers are doubtless more or less familiar with the methods employed in putting up office buildings and business blocks by what is known as "skeleton-frame" construction, in which an iron or steel framework of columns, girders, and joists carries the loads to be supported independently of the stone or brick walls with which the metal is generally incased. This system is becoming more and more extensively employed in the larger cities of the country, for the reason that it permits of the use of thinner foundation walls than would otherwise be the case, while at the same time adding to the fire-proof qualities of the buildings. It cannot be said, however, that iron and steel in this form have yet found their way to any appreciable extent into the construction of private dwellings, but it is doubtless only a question of time, for it is well known that many of the reasons which have led to the introduction of these materials into magnificent office buildings and business blocks apply with almost equal force to the more palatial city residences. This is especially true just now, when the very low price of steel is stimulating its use in the smaller class of buildings where wood would no doubt continue to be employed if there existed a great difference in the cost of the two materials.

The first application of the "skeleton" system to the construction of private dwellings has been brought to our notice by the structural department of the Illinois Steel Company of Chicago, Ill., where a strictly fire-proof residence is now in course of erection, which is expected to mark the beginning of a new era for this type of buildings.

The residence is that of W. H. Reid, and represents the design of Beers, Clay & Dutton, architects, of 218 La Salle street, Chicago. The house faces directly west and is constructed with brick walls, on the interior of which 1½-inch furring tiles are used. The front of the basement, steps, and platform are of granite, while the porch and all the trimmings, including cornices, are of a delicate cream colored terra cotta. The front bricks are of cream color, laid in Flemish bond with white mortar. The porch post, 10 feet long, is in one piece of terra cotta. All the floors and the roof are supported upon steel beams varying in size from 9 to 15 inches, according to the load they are required to carry.

Adjoining the site of this building on the north was an old party-wall, and here it was necessary to make use of cast-iron columns and steel girders. On this side the basement wall is of brick, and supporting the iron columns are three 65-pound rails, each 4 feet long. The 8-inch wall is supported upon the beams running parallel to the old party wall, and, by surrounding them, form a fire-proof covering. In order to hold the brickwork of the rear bay and the walls above, a construction of columns and steel beams is employed.

The rear portion of the third story is to be used as a large balcony. All the posts and other parts for this balcony are of cast iron, thoroughly braced, and covered on the exterior with copper and on the interior with stamped steel. All the stair stringers are of cast and wrought iron.

The basement windows, north elevation

windows, the rear windows in the second and third stories, as well as all the basement and rear balcony doors, are to have plain or ornamental iron guards. There are also to be iron guards over the two skylights. The front porch railings and fences will be of ornamental wrought iron.

The floors of the house are built according to the improved fire-proof system of the expanded metal fire-proof construction, which may be briefly described as follows: Between the I beams of the building, running transversely, are channel iron arches, ranging, according to the weight the floor is to sustain, from 3 to 8 feet apart. Between the channel irons are placed wood centerings, leaving the channel arches and I beams exposed. These arched ribs or haunches are first filled with concrete, over which expanded metal is laid, crossing the arches and covering the false flooring. Above these, concrete is placed to the required thickness. As soon as the concrete is set the false flooring and other woodwork is removed from beneath, leaving a system of steel and concrete arches and flats of concrete having imbedded in their under side a continuous layer of expanded metal.

All the partitions of the house are of 3-inch tile, the roof and rear balcony floor being covered with 6x6x7/8-inch glazed tiles, imbedded in Trinidad asphalt. The basement floor is of concrete laid on the ground, and this in turn is covered with a wood floor. All ceilings are of metal lath and cement mortar.

The finish of the interior will be of mahogany, curly birch, and white oak, painted, the latter being four and five coats of enamel paint. The floors will be of strips of quarter-sawed oak 1 5/8 inches wide. Tiles will be used for bathroom floors and walls, kitchen wainscoting, and the lining of the air shaft. Wire glass will be used for skylights and basement door lights. The plumbing will be first-class in every respect, and will consist in part of porcelain bathtubs and onyx slabs for bowls. There will be a complete system of call bells, speaking tubes, and annunciators, and also conduits and wiring for electric light and telephone.

The heating will be done by means of hot water, and in this connection it is interesting to note the method of running the pipes. These are laid in slots built in the exterior walls, next to which, and under the window seats, are placed the radiators. One of the great difficulties experienced in the plumbing was in connection with the pipes. On account of the large size of the soil pipes, waste pipes, revent pipes, and hot and cold water supply pipes, the architects were compelled to resort to double-thick partitions, leaving a pipe space between, and raising the bath and toilet room floors one step.

The house here shown, as may be inferred from the description, is not a cheap one, and will cost in the neighborhood of $37,000. Owing to the fact that it was necessary to construct a portion of the north wall of iron, and having a plan that gave parallel walls and no recesses or irregular lines, the architects found that to substitute steel beams in place of wood joists cost about $2,000 extra. The architects of this house have also designed and erected many notable buildings in various parts of the country, and may be justly considered pioneers in this new field.—*Carpentry and Building.*

ELECTRIC MOTORS IN BRIDGE CONSTRUCTION

The electric motor is being much used instead of the engine in the construction of a large bridge at Budapest. The pile-driver used to sink a cofferdam, the sheet piling of which is said to consist of rolled iron girders, is motor driven and is capable of driving forty of these beams to a depth of 26 feet in twenty-four hours, the steam machine driving only about three-fourths of this number. Windlasses and centrifugal pumps are also motor driven, and the enclosed or street railway type of motor appears to be unknown, since the direct coupling of the latter was considered inadvisable, owing to moisture. The belt drives, however, serve another purpose, namely, the variation of the speed ratio, the pump speed being necessarily higher as the load increases.

PAINTING IRON WORK

The painting of iron work is one of the most neglected yet important factors in its preservation, and one to which the mechanical engineer rarely devotes much time or thought. The majority of specifications merely state that the iron work is to receive

one, two, or three coats, as the case may be, ignoring entirely the quality of the paint. Perhaps the engineer is not wholly to blame for this, says the *Mechanical World,* as the manufacturers of paint, like other venders of special articles, puff their rival wares, until everyone, except the expert, is quite at a loss what special paint to choose. As a general rule, price is the first thing which influences the choice of paint, after which comes color, and finally covering power. The preservative action is seldom considered, whereas, if this were kept prominently forward, we should have had exhaustive experiments on the subject and some consensus of opinion as to the proper paint to use for iron work, one which would thoroughly preserve it under the most adverse circumstances, thereby saving the loss due to oxidation.

A paint to preserve iron work should possess great firmness, good hardening properties; it should be elastic, and expand and contract readily with the iron at varying temperatures. Of the best paints, those most used are the oxide of iron, and red and other colors of lead paints. Oxide of iron paints possess greater covering power than lead paints in the proportion of three to two. [This may be true of English paints, but nearly the reverse is true in this country.—Editor BRIDGES.] From some experiments which have been made with some of Wolston's Torbay oxide of iron paint, it was found that on a surface of ten superficial yards, it took, for the first coat of oxide, 1 pound; for the second coat 1½ pounds; for the third coat, 2 pounds; while with the lead paint 1½ pounds were used for the first coat, 2½ pounds for the second coat, 3½ pounds for the third coat. It is claimed by the makers of paint from natural oxides, that these oxides possess some mysterious advantages over artificial oxides which have been obtained as by-products from chemicals; that the paints from artificial oxides do not possess good covering powers; that they have not the power of amalgamating with oil, and that they have an acid reaction which necessarily corrodes the iron. This may be the fact in some cases, but we have seen artificial oxide paints which have none of these disadvantages, and which have a decided alkaline reaction, thus equaling, if not rivaling, the natural oxide paint, and, being made from waste products, they are necessarily cheaper. A good paint for iron work should be free from grit, uniform in quality, unchangeable under atmospheric influences, possess great covering powers, and be of an alkaline nature. The whole of these qualities can be tested by the ordinary painter under proper supervision, except the last, which requires chemical knowledge, and we should strongly recommend the users of paint for iron work to test their paints in conjunction with a qualified analytical chemist who has made the subject his study.

Before painting the surface of galvanized iron, it should be washed with an alkaline solution, as the galvanized iron frequently has a greasy acid surface when it leaves the galvanizing bath. In painting structural iron work, the wrought iron should be allowed to weather first before painting, as the oxide which forms on the surface of the iron when rolled will always, sooner or later, peel off, carrying whatever coats of boiled oil or paint there may be put upon it. We have seen this oxide peel off in flakes two feet and three feet square; we know engineers are fond of specifying the iron to be oiled while hot from the rolls, and we have even seen it specified that castings should be coated with boiled oil while red hot. How the gushing engineer expected the castings to be fettled and cleaned before this operation we know not. A good coat of paint improves the appearance of a machine, bridge, or roof, and, although it may seem a minor matter, yet we believe there is money to be saved by careful attention to the quality and price of the paint used on iron work.—*Carpentry and Building.*

BEST FLOORS FOR SHOPS AND ROUND-HOUSES*

In round-house floors we find, among those in general use, brick, concrete, granolithic concrete, cinder, disintegrated granite, cedar block, timber, and plank. Of these, the four most commonly used are probably brick, concrete, plank, and cinder.

Heavy repairs require the use of hydraulic jacks which bring great pressure to bear upon the floor adjacent to the cinder pits. To withstand the pressure requires a wide pit-wall, or else very firm foundation and rigid surface in the floor. In washing out boilers, large quantities of water are used, much of

* Extracted from the report of a committee of the Association of Railway Superntendents of Bridges and Buildings.

which is spattered upon the floor. Besides this, there are numerous occasions for spilling all kinds of oil and grease. And, withall, the demands for cleanliness are unceasing. Not the least of the destructive elements is the rolling of heavy trucks or driving wheels, or the dragging back and forth of jacks and large pieces of machinery.

This committee believes that good vitrified brick, properly laid, will give the best satisfaction in all round-houses which are used for anything more than storage purposes. In this we have a floor that is smooth, firm, hard, and practically indestructible. It is absolutely unaffected by water, heat, oils, acids, or grease, and is easily cleaned, while one important advantage is in the ease with which it can be repaired, since any part may be taken up and replaced by common labor without the slightest injury to the floor as a whole.

The following method of laying brick floors conforms to the generally accepted practice: Assuming the soil to be firm and well drained, excavate the ground to an even surface 8 inches below grade of desired floor. Tamp well with heavy rammers to secure a firm foundation, then fill in with good clean sand or gravel to within 3½ inches of grade, making a crown of about 2 inches between pits for drainage; wet this down well, tamp with rammers, and trim off with straight edge, taking care to get good, even surface. lay brick on edge close to each other, and breaking joints so that tops come one-half inch above grade. After laying, roll bricks with 2,000-pound or 3,000-pound roller, cover the surface with one inch fine sand, and broom it well into cracks, or fill cracks with cement grout. A concrete foundation is recommended by some, but, except in cases where the natural ground is not firm, or where the floor is to be subject to extremely heavy loads, it is not considered necessary. Following is the cost of brick floors as put in on several roads:

Renewing floor in Chicago & Northwestern round-house at Winona, Minn., taking out old plank floor and replacing it with vitrified brick, 21 stalls: Labor, $919.91; material, $1,358.06; total cost of 17,976 square feet of paving, $2,277.97, or 12.7 cents per square foot. Deducting $927.33 for extra work not properly included in paving, the actual cost of laying 16,000 square feet of paving was $1,350.64, or 8.4 cents per square foot. The brick used were made by the Flint Brick Company, of Des Moines, Iowa. In size they were about 8¾x2⅞x2⅜ inches. They are laid on edge, requiring six or seven brick to the square foot.

The cost of a brick floor in the 97x212 feet freight repair shop if the Chicago, Rock Island and Pacific Road, at Horton, Kan., including concrete foundation under rails of nine tracks, brick foundation under truck track, cement drains at three tracks and taking out old wood floor was: For paving, per square foot, 7 cents, of which 5 2-3 cents was for material, and 1½ cents for labor; cost per square foot tearing out old floor, .09 cent; cost per lineal foot concrete under rails, 26½ cents, of which 12½ cents was for labor; cost per lineal foot of drains, 25¼ cents, of which 12¼ cents was for labor; total cost for entire work, 11 cents per square foot, of which 2¾ cents was for labor. If brick floor is grouted with cement (Portland), add one-half cent per square foot.

The Norfolk & Western Railway use a brick made by the Virginia Paving Brick Company. The cost is given per square yard of finished floor about as follows: Brick, including freight, 70 cents; labor necessary to finish, 35 cents; foundation., etc, 20 cents; total per square yard, $1.25=14 cents per square foot.

On the Chicago, Milwaukee & St. Paul Railway, the cost per square yard of brick floor was: Fire-box cinders, nothing; paving brick, 50 cents; preparing foundation, 20 cents; laying brick, 15 cents; total per square yard, $0.85=9½ cents per square foot. Cinder foundation to be not less than 6 inches thick, with top dressing of fine sand 1 inch to 2 inches thick. Vitrified brick laid on edge with 1 inch of fine sand broomed into joints.

On the Erie Railway the cost per square yard of brick floor was: Fifty brick at $6.50 per M., 32½ cents; cement filling, 6 cents; sand cushion, 1 cent; 6 inches concrete, 25 cents; labor laying brick, 40 cents; total per square yard, $1.04½=$0.116 per square foot.

On the Boston & Maine Railway, the brick is laid flat on a layer of bedding sand on well-compacted earth, gravel, or cinders. Joints are left open three-eighths of an inch and swept full of thin cement grout. The cost of such a floor, exclusive of sand and

preparation of substratum, is given at from 6 cents to 7 cents per square foot.

To secure more room for jacking, it is suggested that two pieces of 8x10-inch timber be used in place of one piece of 8x16-inch. This will allow a piece of 5x14 inches, instead of 5x10 inches, along the rail. For the support of the two 8x10-inch sticks, the pit-wall may be bracketed out on the back side. Another suggestion is for the use of two 3x10-inch I beams in place of the 8x16-inch timber. A half-inch plate riveted to the I beams would furnish something to which the rail might be fastened.

A concrete floor with top dressing of Portland cement is recommended by one member as giving a very smooth and durable floor. It can be readily washed without injury, will withstand the effects of heavy jacking, and does not chip if properly handled. Any needed repairs are easily made by common labor. The cost is given at from 10 cents to 20 cents per foot, varying according to thickness of concrete and cost and quality of materials. Similar to this, but with a different surface, is a concrete floor with top dressing of 1 inch of asphalt in place of the Portland cement. The cost of such a floor would probably be from 20 cents to 30 cents per square foot. An objection urged against the asphalt covering is that in hot weather it becomes soft, and liable to indentation under heavy loads, while if a hard asphalt is used it will chip. The repairs to this kind of covering would probably be higher in cost than cement work, as a more expert class of labor would be required in making them.

Cinders form a very cheap, and, for large round-houses, a very poor floor. The cost of putting in such a floor is merely the labor of hauling cinders from a convenient pit, dumping, and going over the top with a roller. If used in small houses where there are but light repairs and no washing of boilers, and if the surface is kept moist and well packed, a cinder floor answers the purpose fairly well. But as soon as it dries off in any spot, there is immediately the gritty dust to contend with, becoming very trying to men and tools, and destructive to machinery.

Disintegrated granite is being largely used by the Union Pacific Railway. It is found in large quantities at Sherman, Wyo. Doubtless the members will recollect seeing last fall, upon the Union Pacific Railway, platforms made of this material. It is understood that this railway is replacing all the old plank floors in round-houses with this granite gravel. Their method of building a floor is about as follows:

The foundation is made of clay, or any material which is convenient and will pack firmly. The filling is carried up to a point about 4 inches from the surface, after being flooded and thoroughly rammed. Over this filling there is laid a 3½-inch layer of equal parts of disintegrated granite and sticky clay. For a finished surface, they spread on one-half inch of the granite gravel. This is set in the yielding clay when it is wet, and hardens when it becomes dry. It is said to make a very firm as well as cheap floor. Second-hand bridge stringers are used around pits for jack timbers and a planked way is laid in front of ends of pits for trucking. The total cost, including removing old plank floor, is given at $92 per stall, all of which approximates 10 cents per square foot.

Cedar blocks well laid form a neat, clean, and durable floor. It is stated that great care must be taken, if any heavy jacking is done, lest the blocks be forced down through the planks of the foundation.

On the Chicago & Eastern Illinois Railway, the cost is given as follows: One square of white cedar blocks, $3.33; 4 cubic yards gravel at 50 cents, $2; labor, per square, $2.75; total, per 100 square foot, $8.08=8.1 cent per square foot. Specifications for this floor are that gravel is to be well rolled or tamped before blocks are put on and blocks in turn to be thoroughly rammed.

A cedar block floor in Chicago avenue round-house, Chicago & Northwestern Railway, costs 11 cents per square foot. At this point planks were used between the gravel foundation and the cedar blocks, as is customary in street paving. Very similar to cedar-block floors are those made from timber blocks sawed from old bridge timbers. Such a floor constructed of 6-inch or 8-inch blocks set on 2-inch hemlock plank, which rest on 3 inches of dry sand, gravel, or cinders, has been used on the Ashland division of the Chicago & Northwestern Railway. The cost is given for 100 square feet: One cubic yard of sand or gravel, 10 cents; 200 feet B. M. hemlock plank, $1.20; 100 square feet paving blocks (sawing), 95 cents; labor leveling sand

and laying plank, $1; labor paving, 60 cents; total cost of 100 square feet, $3.85=3.8 cents per square foot. It will be seen that this is a very cheap floor, and assurances have been made that it is very satisfactory, in spite of the low cost.

To within late years it is probably safe to say that plank floors have been most generally used throughout the country for shops and round-houses. While these floors present a good smooth surface at first, they deteriorate rapidly, especially if built of pine. Most of us have probably experienced the same feeling of exasperation to find a plank floor, which we had carefully patched up three or four months ago, as full of holes and generally as disreputable as ever. If good oak plank is used, the cost approaches or even exceeds that of a good brick floor. Stone flags are mentioned as forming a permanent and economical floor in localities where flags are cheap. But it cannot be called a smooth floor. The cost will vary from 15 cents to 25 cents per square foot.

Granolithic concrete consists of a very fine grade of granite chips and best Portland concrete with top dressing of some cement. A similar surface to that of the ordinary concrete floor would result, but the cost is greater on account of added expense in materials. Cost per foot is stated to be about 30 cents, making it probably the most expensive of any of the floors under consideration.

SHOP FLOORS

For blacksmith shops or foundries, the natural earth frequently forms a very suitable as well as substantial floor. In localities where the soil is too soft in its natural state, the addition of cinders or clay will solve the problem cheaply and satisfactorily.

In machine shops the conditions are different, and here we find the recommendations almost as varied as are those for round-house floors. A brick floor in a machine shop answers many of the requirements, but there is good evidence in support of the objection that men cannot stand all day on such a floor, or upon a surface of concrete or asphalt, without feeling the bad effects of cold upon the feet. This difficulty is overcome to a large extent by the use of slatted floor racks or platforms at the machines where operatives stand. When machines are set upon a brick floor, there should be special provision made for foundation. But this can hardly be urged as an objection, as it is necessarily the case with heavy machines under almost any circumstances.

A bedded plank floor has recently been laid in an extensive shop plant of the Boston & Maine Road. The earth is well compacted and brought to the proper surface and a bed of coal-tar concrete put down in three courses. This bed is 4 inches thick when finished. The specifications are that the stones of the lower course shall be not less than 1 inch in diameter, and those of the second course not more than 1 inch in diameter. Stones of each course to be well covered with tar before laying and thoroughly rolled afterward. The finishing course to be composed of good, clean, sharp sand, well dried, then heated hot and mixed with pitch and tar in the proper proportions. This is to be carefully rolled and brought to a true level to fit a straight-edge. Roller to weigh not less than 700 pounds on a length not exceeding 22 inches. On this finished surface of the foundation there is spread a coating one-quarter inch thick of best roofing pitch put on hot, into which the lower course of plank is laid before it cools. Care must be taken to have the plank thoroughly bedded in the pitch, and after laying the joints must be filled with pitch. If vacant places occur under plank, they should be bored and filled. The finishing flooring is laid across the lower and thoroughly nailed.

For the lower course, 2½-inch spruce plank s. l. s. is used, and for the upper 1½-inch s. l. s. spruce plank. It is also noted that the lumber for lower course should be fairly seasoned, and that of the upper course well seasoned before using. The cost of such a floor is given at 18 cents per square foot, using spruce lumber.

For paint shops and car shops, a brick floor has been found very satisfactory. The committee believes that a brick floor, generally speaking, is the most economical, durable, and satisfactory floor for shops, as well as for round-houses.

EDITORIAL OPINION.

CUBA, PORTO RICO AND THE PHILIPPINES do not at present offer much of a field for the study of bridge design. The Spanish people never discovered that the way to make their colonies profitable and a source of revenue would have been to build highways and railroads, together with such other public improvements as would have tended to local development of the countries and their peoples. Had they appreciated this, we are not sure that there exists sufficient engineering talent among them to have planned and carried out the building of scientific roads and bridges.

In Cuba there are numbers of engineers who received their education in the United States, and, had they been given free rein, would no doubt have done much more than was actually accomplished.

The last bridges that were planned in considerable number for the Havana system of railways were short plate girders or deck riveted lattice span of European outline and general design, the measurements all being given in the metric system. The bridge spans and ore dock in Santiago province, at Baiquiri, are of American design, the approach spans being deck trusses and the dock proper founded on tubular piers.

The roads in Porto Rico are few in number, and we believe the majority of the bridges are of stone. A recent native writer on the subject of a system of electric railways for the island, which would use water power from the numerous mountain streams, says that fine stone for building purposes is abundant, and advocates the construction of stone bridges for such roads as may be built. We presume, however, that the establishing of steamship lines from the States to San Juan and other ports will soon make it possible for steel work to be delivered there at reasonable figures.

APPROACH TO DOCK AT BAIQUIRI.

In the Philippines, the country is practically unknown outside of the immediate

vicinity of the larger towns, and only in these localities have bridges been built in anything like a permanent manner. Access to the interior is had mainly by the streams, and on the land the narrow trails are provided with the primitive foot log, which is in some cases provided with a pole for a hand rail. Some structures may be seen of similar construction to the ingenious wooden bridges of the Japanese, with timbers or logs in the shape of rafters connecting the opposite sides of a gorge or cañon, with the footway laid across on a level with the apex.

The stone bridges about Manila are almost without exception of very rude design, and have very short spans, like the one shown in the sketch. One over the Pasig river has six spans, with very thick piers and huge pointed cutwaters. One arch which was destroyed by an earthquake has been replaced by timber joist, which are strengthened by wooden brackets or cantilevers on each side.

Others of the bridges are no more than timber trestles, but the most pretentious, perhaps, is the iron suspension bridge over the Pasig, with its obelisk-like stone towers.

The development of all the islands by American capital will lead to the building of extensive highways and railways, and we doubt not the use of a great tonnage of American bridge material.

DOCK AT BAIQUIRI.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES should be in use for bridge and structural work, more especially than for any other class of engineering work. The measurements for a steel structure are usually sent to a bridge company in feet and decimals of a foot, and all dimensions can be conveniently retained in that form in making the original design and the estimate, but when the detail drawings are made, they must be translated from decimals of a foot into inches and fractions of an inch, down to thirty-seconds, and occasionally to sixty-fourths. The progress of the detailing requires frequent conversions of lengths into decimals for the purpose of making calculations, and the resulting dimensions must be converted back again. The spacing of rivets, for example, requires frequent additions, for checking up, of dimensions in feet inches, half quarter, eighth, sixteenth, and thirty-second inches, which is accomplished with great mental weariness by the draftsman. He becomes used to it, as one can to some severe kinds of sickness, even becomes expert at adding a great number of different fractions,

but, aside from the severe labor, there is a needless amount of time so consumed.

One of the first drawings to be made for any piece of work is the masonry plan, with dimensions in feet, inches, and fractions of an inch. This is sent out to be used in locating the foundations, and these figures must all be reduced back to the decimal form. Ridiculous, is it not? Is this to be one of the benefits of civilization which we are to inflict on our new colonial possessions, where to some extent the metric system has already been used?

The increase in the foreign business of the structural steel mills has made it convenient, if not absolutely necessary, for one of the large mills to publish tables of shapes, round and square bars, and plates, with the dimensions in millimeters, areas in square centimeters and weights in kilograms per meter. The values in feet, inches, and pounds were readily reducible to these metric units without the use of more than two decimal places to give the accuracy desirable. This may be accepted as a beginning of a very much desired change. No matter what legislation may be enacted by Congress with reference to the compulsory use of the metric system, it is only the matter of a very short time until all tabular work will require conversion, and some steps should be immediately taken toward the systematic prosecution of it. A committee might be appointed by the American Society of Civil Engineers, to consist of members engaged in structural work, to coöperate with similar committees from the Association of Engineering Societies, and the Association of Railway Bridge and Building Superintendents, to promote the change under an agreement from the persons directly interested, to apportion the work among them so as to avoid duplication of labor, and, finally, to arrange for the publication of tables of common value, in some way similar to that of the German Engineers' Handbook.

THE PHILIPPINE ISLANDS—A CHARACTERISTIC BIT OF MANILA, SHOWING A SPANISH CHURCH AND A BRIDGE OVER ONE OF THE STREAMS THAT RUNS THROUGH THE CITY.

There is little trouble to be apprehended in having the persons who are directly interested come to an agreement respecting a change to the metric system, but there will be a chance for considerable missionary work with those indirectly interested, but whose coöperation must be had.

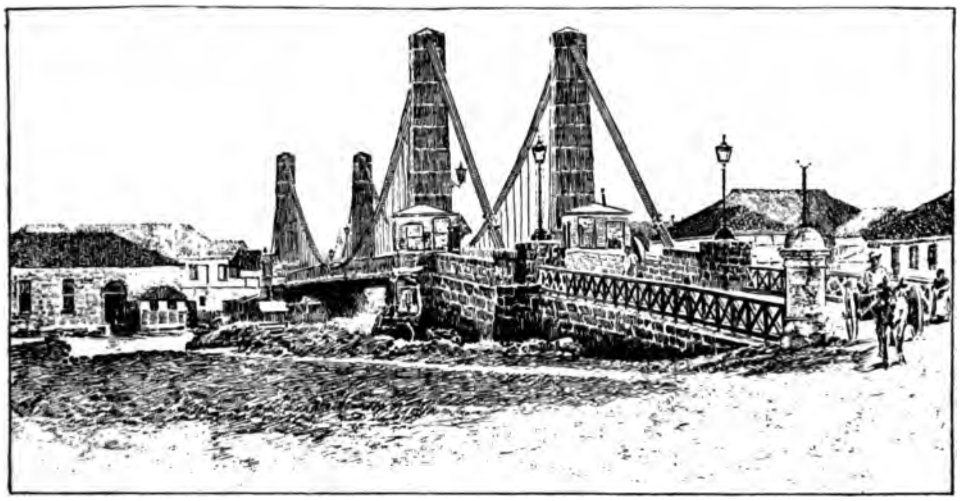
The argument of most weight must be the great saving in time—and, consequently, in money—that will be effected when the dimensions from start to finish will be in decimal form for fractional values, to say nothing of the lessened chance for error and consequent loss. Let those who are vitally interested begin the movement at once.

IMPROVEMENTS IN MACHINERY for shops are so marked at times as to call for especial comment, and space has been given to showing a few of the more notable recent machines. This calls attention to the necessity of charging up greater percentages than is practiced by some shop managers, for depreciation, in order that the necessity for replacing old machines by improved ones long before the old ones are worn out may not cause trouble in the financial department. Assuming, of course, that there are few concerns like one recently told of, the manager of which took no account of depreciation, saying that his machines would last as long as he cared to stay in business—most likely a very short time.

Machines used for bridge work do not, many of them, depreciate as rapidly as machines used in other classes of work, and consequently a smaller percentage has been taken than in the case of very light tools, such as are used in light manufacturing, often about 5 per cent, as against 10 per cent in the latter case.

During the past few years profits have so nearly reached the vanishing point that many shops have had no chance to declare dividends, not to speak of creating a surplus for betterments. Hope has been entertained, perhaps, that prices would improve, but the larger firms have added improved machinery to reduce costs, and as a result prices remain low, or get lower. The only things to be done, then, by the firms who have a selling price near the cost line, is to go out of business, use a surplus, if there is one, to make necessary improvements, or else interest new capital enough to do so, in hopes of greater profits than before the low prices began.

The work of bringing a plant up to a reasonable degree of efficiency does not call for an enormous outlay, if the heavy tools are not badly worn, as electric motors can be fitted to them with small expense. The greatest expenditures will need to be made for an entire new power plant, and new finishing tools, where the greatest improvements have been made.



THE IRON SUSPENSION BRIDGE OVER THE PASIG RIVER, MANILA. THE STREET LIGHTS SHOWN IN THIS AND OTHER VIEWS OF MANILA ARE OIL LAMPS. ELECTRIC LIGHTS HAVE RECENTLY BEEN PUT UP IN SOME OF THE PRINCIPAL STREETS AND BUSINESS HOUSES.

The plant that is in good shape, or that has been remodeled so as to have a good margin of profit, should, in addition to an ordinary percentage for depreciation, set aside a liberal amount each year with which to buy, as may be found desirable, the latest improved machines. There is no reason to believe that the future will not bring forth as great changes in tools and machines as the past, and it is possible that there may be greater ones.

The manager may desire to make a "good showing," or he may be under pressure to pay large dividends, or as large as possible, and neglect this important matter—"rob Peter

to pay Paul"—but the evil day will come, and such temptations should be resisted in the interests of "good business" and ultimate gain.

THE CONCENTRATION OF INDUSTRIAL PLANTS at a few localities, or in a few regions, seems more probable now than ever before, on account of the rapid and wonderful development of water-power electric plants. At Niagara, the company that originated the utilization of power from the falls has been a great success, and several other ambitious schemes seem to be a promise for a great manufacturing district in the Buffalo region.

Now the Sanitary District of Chicago is arranging to have some company use the power from the drainage channel, which will develop some 30,000 horse-power. This will inure to the benefit of Chicago, and be some assistance in developing the manufactures of the region tributary to the city.

The Western States, particularly the Rocky Mountain and Pacific Coast regions, are rich in possibilities for such plants. In Colorado, a new plant of the Colorado Electric Company has recently been put into operation to supply power to the gold mines, and the possible sources of water power are very numerous.

There are various important plants on the north Pacific coast, and one, the Snogaulmie transmission, is especially notable on account of the long distance the current is carried. In Southern California, where fuel has been very expensive, there are four important water-power electric plants, the San Antonio, with transmissions lines to Pomona, a distance of fifteen miles, and to San Bernardino, thirty miles; the Redlands, with several lines, the longest twenty-two miles, to Riverside; the San Gabriel, carrying current to Los Angeles, a distance of twenty-three miles, and, most important of all, the Southern California, with wires from Santa Ana Cañon, a distance of over eighty miles, to Los Angeles, the tension of transmission being 33,000 volts. Whether or not this will result in an increase to any great extent in the manufactures of that section is somewhat doubtful, as raw material of many kinds is not to be had. But it does show the course of events in the problem of power production, and is a suggestion to other parts of the United States where water power is available.

Some years ago some of the engineering journals exploited a scheme of some New York capitalists for the pumping of crushed coal to market in pipe lines, with water as the transmitting fluid. The success of long-distance electric transmission at high tensions leads us to believe that instead of piping coal to market, the coal will be burned under boilers at the mines to generate steam for driving electric generating plants, and the power taken to market in the form of electric current on wire circuits. The discovery of a practical method of generating electricity from fuel, without the use of steam plants and dynamos, would, of course, make the chances better for such transportation of power, but with improved methods and means of long distance electric transmission, we believe the loss would be small, at least as small in the east as on the Southern California lines, where the weather conditions are worse in many respects.

Should this prove to be practicable—and it certainly would be more feasible than the idea of piping coal, or the idea of generating gas from coal at the mines and piping it to market—then the number of possible manufacturing districts would be increased. There would be regions of about 150 miles' radius about each coal district, and of the same size wherever water power is available.

While many will decline to believe that present conditions are going to change materially, there is room for much study of the possibilities, so as to be prepared to accept the "inevitable," if it comes.

Reviews and Reports.

[This department will be open to reviews of technical books pertaining to Bridges and Framed Structures as well as to reviews of the publications and reports of technical societies and schools. We shall be pleased to receive early reports of technical society meetings and abstracts of papers of especial interest to our readers.]

The proceedings of the American Society of Civil Engineers for January contains the report of the annual meeting at New York on January 18, 1899. The election of officers resulted in the choice of Desmond FitzGerald, of Boston, as president. The membership of the society consists of 2,124, of whom 1,331 were full members.

The paper by Mr. E. L. Corthell, presented on February 15th, "The Approaches and Transportation Facilities of the Paris Exposition of 1900," was published in advance, as is the custom, to allow discussion. "During a recent visit to Paris, the author became much interested in the engineering features of the Paris Exposition of 1900, and undertook to collect, for presentation to this society, such information as was obtainable on certain interesting and important points. The engineers in charge of the several works, fully understanding this purpose, afforded him every facility for inspection, and kindly furnished him plans, reports, and other data.

The Eiffel Tower and the Palais des Machines are the only old structures that have been retained, and the Tower is to be painted sky-blue, so as to blend with the sky and make it less prominent. Electricity will be made the main exhibit of the Exposition. Mr. Corthell then describes in order, the Alexander III. Bridge, the Orleans Railroad extension, and that of the Western Railroad, the Movable Sidewalk and Electric Railroad, the Metropolitan Underground Railroad, and the enlargement of the Lyons Station.

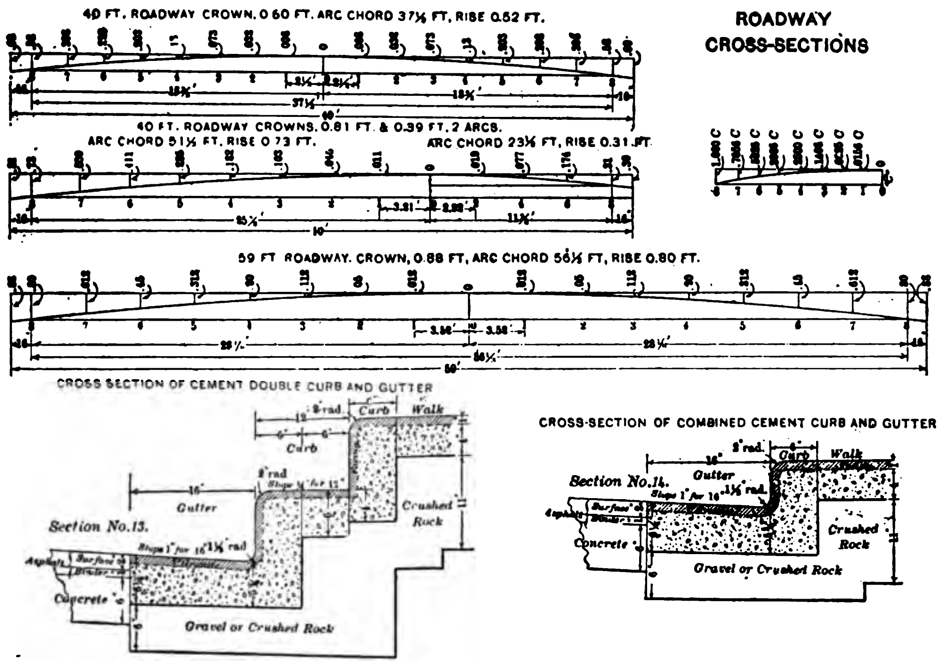


Fig. 8.

In 1823 a project was brought forward and approved for a suspension bridge at the site of the Alexander III bridge. When the cables were swung and the floor laid, joints were opened in one of the counterforts and

a water conduit nearly broke in two. With this as an excuse, the opponents of the bridge secured its removal.

"The architectural features of the new bridge were worked out by the architects, Messrs. Rénard and Cousin, with a view of harmonizing the entire structure with the architecture of the Exposition and other features of the locality. There were three points to consider: *First*, not to interfere with the perspective of the Invalides, viewed from the Champs-Élysées; *second*, not to injure the appearance of the Seine, seen from the Pont de la Concorde; *third*, to make the width in proportion to the width of 100 m. (328 feet) of the new avenue. On the other hand, the width of clear span for navigation must take into account a bend in the river at the location, which throws the current upon the right bank. To restrict the width at this point would seriously interfere with the navigation by convoy. Very laborious study was given to all these points. In the structure as finally designed, all these requirements have been met."

The span is a three-hinged cast-steel ske arch, the upper portions and floor being of rolled steel. The clear width of the river between quay walls is 508.5 feet, and the span of the arch 352.69 feet. The roadway is 65.6 feet wide, each sidewalk 32.8 feet wide, while the 2 per cent grades each way from the center are joined by a vertical curve of 2,624 feet radius. The ribs will be joined by bolting, to facilitate erection, as the river cannot be obstructed, and a truss traveler spans the entire river, from which the erection is carried on. The foundation work, which was referred to in a former issue, is of huge pneumatic caissons in the shape of parallelograms 109.88 feet by 144.36 feet, each one being divided into five parts. When completed and filled with concrete, each one will take up a thrust of 288 tons per square meter, or about 26.8 tons per square foot.

In the extension of the Western Railroad, the river is crossed, and "the trusses of the bridges and viaducts are quite well shown on the profile; the longest span, that over the navigable way, is quite artistic."

"The station"—of the Paris, Lyons & Mediterranean Railway—"is now being remodeled at very great expense, said to reach $8,000,000. The new train shed is completed, the work having been begun about two years ago. The plans for the main structure have just been approved, and work upon it will soon be begun. It will be very extensive, and will be, when completed, the finest and most commodious station in Paris."

The American Society of Civil Engineers' Proceedings for February Contains the full report of the annual meeting held at New York on January 18 and 19, 1899.

One of the most important matters was the report of the Committee on Standard Time, which was appointed on June 15, 1881, and has been continued ever since. The hour zone feature has been adopted throughout North America, and has been accepted in Europe, India, Japan, Australia, and South Africa. The 24-hour system, which is in use by the society and which has been so much laughed at by some, is in use on the Canadian Government railways between Halifax and Montreal, and on every line of railway north of the 49th parallel west of Lake Superior. It is used in India and China, and enforced by law in Belgium and Italy.

The subject of an International Institute of Engineers was brought up by Mr. E. L. Corthell, who has devoted much time toward its accomplishment. The endeavor is being made to further the scheme by holding a congress of engineering at the Paris Exposition. The efforts which have been made to this end were reviewed and the matter referred to the Board of Direction.

Mr. Willard A. Smith, Director of Civil Engineering and Transportation for the United States Commission to the Paris Exposition, addressed the meeting on the subject of an engineering exhibit.

The advance publication of the paper on "Street Grades and Cross Sections in Asphalt and Cement," by Robert P. Woods, Jun. Am. Soc. C. E., is in this number. In arranging the grades and cross-sections of streets in Wabash, Ind., a departure was made from the customary methods.

The erection of buildings had preceded the establishment of grades so that adjacent store floors were at different levels, and there were few localities where opposite sidewalks were on the same level. The adjustment was effected by using steps in the curbs. "The three usual forms for roadway crowns are the parabolic and circular curves, or a combination of either one with tangent sides. Of

these, the first two are nearly always alike, while the last may be arranged quite differently from either. The form used by the author was a parabolic curve, and yet, for all practical purposes, it might be called the segment of a circle, since a calculation of both curves shows their corresponding ordinates to be almost identical where the proportion of rise to span is so small as prevails in the construction of city pavements.

"The distance from the edge of the gutter to the crown line was divided into eight equal parts, the division points being numbered consecutively, from 'o' at the crown line, to '8' at the gutter," as shown in the cut at the right.

"The amount of crown of each roadway from the face of the curb to the crown line is 3 per cent of the horizontal distance between the two points named. Of this amount, the gutter has a uniform slope of 0.08 feet in its width of 16 inches, and the remainder is the rise or crown for the asphalt portion. In the case of a roadway 40 feet in width between the curb faces, with the crown line in the center, the total rise or crown is 0.60 feet, and the crown in the asphalt portion, which is included between the gutter edges, is 0.52 feet. This latter rise, as before stated, is proportioned on the form of a parabolic curve."

"The crown and gutter lines in each block of pavement are on parallel longitudinal grades throughout, excepting the small deviations made on Market street, on either side of the Wabash and Market street intersection. These roadway grades range from a minimum of 0.35 per cent to a maximum of 2.42 per cent.

"The cross-slope of the sidewalks is on a uniform inclination from the property lines of the streets to the curbs, and varies in amount from .015 per cent to an occasional 4 per cent grade."

The proceedings of the American Society of Civil Engineers for March, 1899., contains reports of the March 1st meeting, at which the paper on "Street Grades and Cross-Sections in Asphalt and Cement," by R. P. Woods, Jun. Am. Soc. C. E., was read and discussed. The discussion is printed in full, developing the fact that the subject was one of much interest and one which is seldom met in a satisfactory manner.

At the meeting of March 15th, Mr. Cope Whitehouse delivered a lecture on "The Reservoirs of the Nile," which was illustrated by Stereopticon views.

At the meeting of the Board of Direction, February 28, 1899, general rules for the acceptance and presentation of papers to the society were adopted, and we extract some of them:

"No formal papers shall be set down for presentation to the annual convention, but in lieu thereof discussion will be asked for at each annual convention and at each annual meeting, on all papers which have been published in proceedings during six months immediately preceding each of these general meetings."

Editorial rules for publications of the American Society of Civil Engineers:

"1. In preparing all papers, discussion, and correspondence on technical subjects for the press, the third person shall be used. The contributor of a paper shall be referred to as 'the author,' a correspondent as 'the writer,' and one who contributes to the verbal discussion as 'the speaker.'

"2. All redundant matter, interrogations which the text of the paper renders needless, and sarcastic forms of expression, shall be excluded.

"3. All errors in orthography and grammar shall be corrected. In cases where there are two correct spellings, that to which preference is given by the best authorities shall, for the sake of uniformity, be adopted.

"4. Ambiguous or obscure statements shall be restated in clearer form, care being taken, however, to preserve as far as possible the language and style of the author.

"5. No unnecessary changes in wording shall be made.

"6. Whenever time will permit, a proof of any paper and discussion in which any changes indicated in Rules 4 and 5 have been made, shall be submitted to the author before publication. But in this connection it should be borne in mind that it is not always possible, on account of lack of time, to submit a proof, and that inasmuch as the first publication of all discussions will be a preliminary one, necessary corrections may be made before the final issue in the Volumes of *Transactions*.

"7. Oral discussions shall be reported stenographically. From this report a rearranged form of the matter brought out by the speaker

shall be carefully prepared and forwarded to him, together with the full report of what he was understood to say, and, whenever time permits, any modifications or amplifications of this statement shall be printed in *Proceedings*. When it is not possible to secure the approval of the sneaker prior to this publication, he shall be allowed to make corrections, changes, or amnlifications in his discussion before it is published in *Transactions*."

A paper by L. M. Hoskins, Esq., "The General Criterion for Position of Loads Causing Maximum Stress in any Member of a Bridge Truss," is given advance publication. The author does not discuss the merits of "Typical Engine Loads" as against "Equivalent Uniform Loads," but attempts to unify the theory of maximum stresses due to moving loads. The subject is taken up in a very logical manner. The generality of the discussion is first set forth, then definitions and notation, after which the deduction of criterion for maximum or minimum stress is made. Influence diagrams are fully discussed and their application in determining the greatest maximum. Then follows a summation of general results and examples of numerical applications. We do not go more fully into the subject, as each engineer has a method of his own for computing live loads which is to him an open book, and time is seldom found in practice for the trial of various methods.

The discussion on "Dry Docks—Stone vs. Wood," at a special meeting on February 10, 1899, brings out the fact that the United States is the only government which has directly employed wood for entire docks.

The matter is summed up in a terse manner by Mr. A. P. Boller, M. Am. Soc. C. E. "It is astonishing that a controversy regarding the relative merits of stone and wooden dry docks should be given serious consideration by a great government like that of the United States. * * * There are some questions that have only one side, and this is one of them. * * * There is but one thing for the United States Government to do, and that is to build stone docks, even at the risk of hurting the feelings of existing dry dock companies."

Vol. I, No. 3. June, 1899. Price, 30 Cents.

BRIDGES

AND FRAMED STRUCTURES

AN ILLUSTRATED MONTHLY MAGAZINE

FOR
ENGINEERS
ARCHITECTS
INSPECTORS
SUPERINTENDENTS
MANUFACTURERS

VIADUCTS
BUILDINGS
MASONRY

LEADING FEATURES OF THIS NUMBER

THE D·H·RANCK·PUB·CO· CHICAGO·

Contents for June, 1899.

*Illustrated.

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VOL. I. Bridges and Framed Structures. No. 3.

AUTHORS AND THEIR ARTICLES IN THIS NUMBER.

E. McL. LONG.—Born at Big Island, Virginia, in 1869. Graduated with degrees of C. E. and B. S., at University of Virginia, 1889. Associate Member of American Society of Civil Engineers. From summer of 1889 to summer of 1894 employed on and in charge of government surveys in Texas and Indian Territory under the U. S. Geological Survey and U. S. General Land Office. In summer of 1894 established office in Washington, D. C., as Civil Engineer, with specialty as designer and consulting engineer of structural work, and inspector of materials of construction. Since establishing office has designed structural part of and inspected material for a good many large buildings in Washington, D. C. For the last two years besides the work relative to Washington office, has been engaged in inspecting material for the new U. S. battle ships and torpedo boats; most of this time being spent in the large steel plants and structural works of Pittsburg, Pa. Office 902 F. St., N. W., Washington, D. C.

JOHN CASSAN WAIT.—Born in Norwich, New York, 1860; graduate civil engineer Cornell University, 1882; Master of Civil Engineering, with the highest distinction, 1891; Bachelor of Laws, Harvard Law School, 1891; has been engaged successively as a civil engineer in the survey, location and construction of telegraph, gas, oil and railroad lines—in the erection of buildings and structures—in the design and manufacture of cars and trucks and the erection of shops for the same; for several years instructor and assistant professor of engineering, Harvard University; sometime associate editor *Railroad Gazette;* editor 1895 edition Car-builders' Dictionary; author "Engineering and Architectural Jurisprudence," 1898; author "Law of Boundaries, Easements and Franchises, and Field Operations in Engineering" (in press); member of Cornell Association and of the American Society of Civil Engineers, Railroad and other clubs; now attorney and counsellor at law, 220 Broadway, New York; specialist in engineering and architectural jurisprudence.

H. W. PARKHURST.—Graduated from Brown University in 1868; engaged in general civil engineering work in an old-established office in Providence for about two years; in 1870 was an assistant engineer on the construction of the Hannibal Bridge across the Mississippi River; in 1873 was Resident Engineer of the Louisiana Bridge across the Mississippi River; in 1874 was locating and constructing engineer on the levee line extending 52 miles south from Quincy, Ill., on the east bank of the Mississippi; in 1876, chief engineer in charge of construction of about 35 miles of the St. Louis, Keokuk and Northwestern Railroad; in 1878 resident engineer in charge of an addition of 45 miles of the extension of the Chicago and Alton R. R. from Mexico to Kansas City, and later in the same year, and in part of 1879, was assistant engineer and finally resident engineer in charge of the Glasgow Bridge across the Missouri River; 1879-80 principal assistant engineer in charge of construction of Plattsmouth Bridge across the Missouri River; in 1881-82 principal assistant engineer in charge of Bismarck Bridge across the Missouri River; 1882-83 principal assistant engineer in charge of construction of the Blair Bridge across the Missouri River; in 1883-84-85 in the office of George S. Morison, in charge of various bridge and other work; in 1885-86-87 in the employ of Geo. S. Morison in connection with several large bridges across the Mississippi and Missouri and Ohio Rivers; in 1889-90 resident engineer of the Merchants' Bridge

across the Mississippi River at St. Louis; in 1891 office engineer for E. L. Corthell, Chicago; from 1892 to the present date, engineer of bridges and buildings Illinois Central Railroad.

FRANK C. OSBORN.—Graduated at Rensselaer Polytechnic Institute, Troy, N. Y., in the year 1880. Accepted at once position of assistant engineer to Louisville Bridge and Iron Co., Louisville, Ky. In a few months was made principal assistant engineer, and held the position until March, 1885. Resigned to accept similar position with the Keystone Bridge Co., Pittsburgh, Pa. Held this position until 1887. Entered firm of G. W. G. Ferris & Co., inspectors of steel construction. Retired from the firm in 1889, and took position as special assistant engineer to Mr. Max S. Becker, chief engineer of Ohio Connecting Railway, then building a bridge across the Ohio river at Pittsburgh. From this position to King Bridge Co., serving as chief engineer for three years. Since 1892 in independent practice as designer and inspector of steel construction, doing business under the name The Osborn Co., civil engineers. Member of The American Society of Civil Engineers, also of The Institution of Civil Engineers. Was president of The Civil Engineers' Club of Cleveland. Has published general specifications for highway bridges, for railway bridges, and for bridge substructures. Also a hand-book for engineers, "Tables of Moments of Inertia and Squares of Radii of Gyration."

CHARLES EVAN FOWLER.—Born in Washington County, O.; after completing common school work at Marietta, served with large business house in Portsmouth, O.; took course in railroad and bridge engineering at Ohio State University; after employment as instrument man on preliminary railroad surveys became bridge engineer of the Hocking Valley Railway; was employed with large bridge concerns as designer, and by The Indiana Bridge Co. as engineer of construction; spent two years in Southern California on combination bridge work and on irrigation engineering; accepted position as estimator for Youngstown Bridge Co. in 1892 and six months later was promoted to chief engineer, which position he held for over six years. During this time the Knoxville arched cantilever, the Market St. plate girder arch at Youngstown, and numerous large railway and municipal bridges, were constructed under his direction.

Engaged at present in private practice, member firm of Foyè & Fowler, New York City. Is a member of American Soc. C. E., author of "The Cofferdam Process for Piers," "General Specifications for Steel Roofs and Buildings," "Engineering Studies," and numerous technical articles in Engineering News, Stone, and the Engineering Magazine.

LOWER NEW YORK AND THE BATTERY.

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BRIDGES AND FRAMED S[illegible]

VOLUME I. JUNE [illegible]

THE USE OF STONE [illegible]

A STONE wall i[illegible] face to back, [illegible] rests. Th[illegible] and represents stability [illegible] All massive structures [illegible] centuries have been [illegible] with no other materia[illegible] in viewing an edifice of this character, [illegible] rendering, one cannot but be impressed [illegible] The walls sustain the weight of the [illegible] openings for doors and windows, thus show[illegible] to do the work for which they are designe[illegible]

We have become so accustomed to looking [illegible] walls of buildings, as the strength-giving materi[illegible] it is rather hard for us to consider it otherwise. [illegible] architect in applying a covering of stone to a structure [illegible] to create the impression that the building owes its [illegible] ing. This hallucination has been partly produced [illegible] basement walls and reducing the size of windows [illegible] them deep reveals. While this form of constru[illegible] the eye, as we are now trained to look at stone [illegible] certainly very undesirable, from an economic sta[illegible] expensive and every extra pound causes an in[illegible] umns, and from a practical standpoint, since [illegible] office or store room is to have a maximum [illegible] stances, however, where light rooms and [illegible] the designer, the stone is applied so as to produce [illegible] the ground floor of a high building is used [illegible] doors occupy nearly all the wall space and we see [illegible] supported by stone piers scarcely sufficient in size to support [illegible] weight, and stone beams or flat arches three feet [illegible] posed load of hundreds of tons over a span of twenty [illegible] however, class this as an architectural fraud, for [illegible] stone is not doing the work as represented.

However applied, stone has become very popular [illegible] ing for the fronts of steel constructed buildings [illegible] in the structural strength of the building, it still [illegible] form in affording a protection against the weather [illegible]

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BRIDGES AND FRAMED STRUCTURES.

VOLUME I. JUNE, 1899. NUMBER 3.

THE USE OF STONE IN SKELETON CONSTRUCTION.

A STONE wall is a rigid mass of solid stone and cement from face to back, and is as durable as the foundation on which it rests. Through all ages it has been a symbol of strength, and represents stability and stolidity.

All massive structures and those designed to stand through centuries have been built of stone, or stone and cement, with no other material entering into their construction; and in viewing an edifice of this character, whatever may be its architectural rendering, one cannot but be impressed with its appearance of strength. The walls sustain the weight of the building, and are thick, with small openings for doors and windows, thus showing to all observers their ability to do the work for which they are designed.

We have become so accustomed to looking upon stone, when used in the walls of buildings, as the strength-giving material of the structure, that it is rather hard for us to consider it otherwise. It is, therefore, that the architect in applying a covering of stone to a structural steel frame endeavors to create the impression that the building owes its stability to this covering. This hallucination has been partly produced by constructing heavy basement walls and reducing the size of windows to a minimum and giving them deep reveals. While this form of construction may be pleasing to the eye, as we are now trained to look at stone work, it is a fraud, and is certainly very undesirable, from an economic standpoint, for stone work is expensive and every extra pound causes an increase in size of beams and columns, and from a practical standpoint, since the most desirable thing in an office or store room is to have a maximum amount of light. In most instances, however, where light rooms and economy are the prime objects of the designer, the stone is applied so as to produce very queer results. Where the ground floor of a high building is used as a store, the windows and doors occupy nearly all the wall space and we see twenty stories of masonry supported by stone piers scarcely sufficient in size to support their own weight, and stone beams or flat arches three feet deep carrying a superimposed load of hundreds of tons over a span of twenty feet. We can hardly, however, class this as an architectural fraud, for it is self-evident that the stone is not doing the work as represented.

However applied, stone has become very popular, at least, as a covering for the fronts of steel constructed buildings, and while it plays no part in the structural strength of the building, it still has its own duties to perform in affording a protection against the weather, both for the interior of

LOOKING UP BROADWAY, NEW YORK CITY.

the building and for the steel work. So, from the top of the beam at one floor level to the bottom of the one above, it is a stone wall, and as such acts an honest part, and it is an error to say that a steel skeleton is covered with a veneering of stone, for the stone is a necessary part of the structure, and the completed wall is a combination of stone and steel in which each material has its duty to perform.

During the period when the steel skeleton constructed building was first being brought into use, the question was often asked whether two materials of such different physical natures as stone and steel could be joined together to form a solid whole. This question has been well answered by the number of examples we have, in none of which have the different rates of expansion and contraction damaged a building. This difference is not as great as most people would suppose. For a rise of 100 degrees in temperature, steel expands one-eighth of an inch in sixteen feet. For the same rise in temperature, granite expands one-eighth of an inch in twenty feet, and marble one-eighth of an inch in eighteen feet. According to these figures, since the stone is exposed to the extremes of temperature and the steel is protected, we might infer that the stone expands or contracts more than the steel. However this may be, since no practical inconvenience is produced, we will let the question drop, and confine our attention to methods of building the masonry to the steel.

The typical steel skeleton building is one in which the frame of steel is designed to carry all permanent and temporary loads and convey such loads through its columns to the column foundations and among the permanent loads is included the weight of the walls. The walls rest on beams, commonly called spandrel beams, at each floor level, and thus each wall is the height of one story and has only its own weight to sustain, whether it incloses the first or twentieth floor rooms.

The problem that presents itself to the architect is to construct a wall to fill up a rectangular opening in the side of a building. As a foundation for this wall he has a steel beam, or a combination of beams to limit its height; he again has beams similar to the foundation beams, and to limit its extent laterally he has steel columns. The foundation beams are designed to carry the weight of the superimposed wall with a minimum amount of deflection and the wall must be designed to be as light as is consistent with strength and its efficiency as a protector against the weather. It is better that this wall should be entirely of stone than of brick with a stone facing.

As steel buildings are at present constructed, another condition to be fulfilled is that all beams and columns must be protected against the weather. This will necessitate the outside of the beams and columns being at least 8 degrees within the building line.

Since the architectural lines of every building are somewhat different, the spandrel beams must be designed, or rather modified, to meet the special cases, and in order to arrive at the most substantial results the architect and the designer of the structural steel should work in unison. Generally the architectural lines of a building, and its adornment, are designed first, and then the structural steel frame is designed to carry a wall of known shape and weight. This is practical, for before an engineer can design a girder to carry a load he must know its weight and how it is to be applied. But still if this method of procedure is carried too far, and the lines of the building

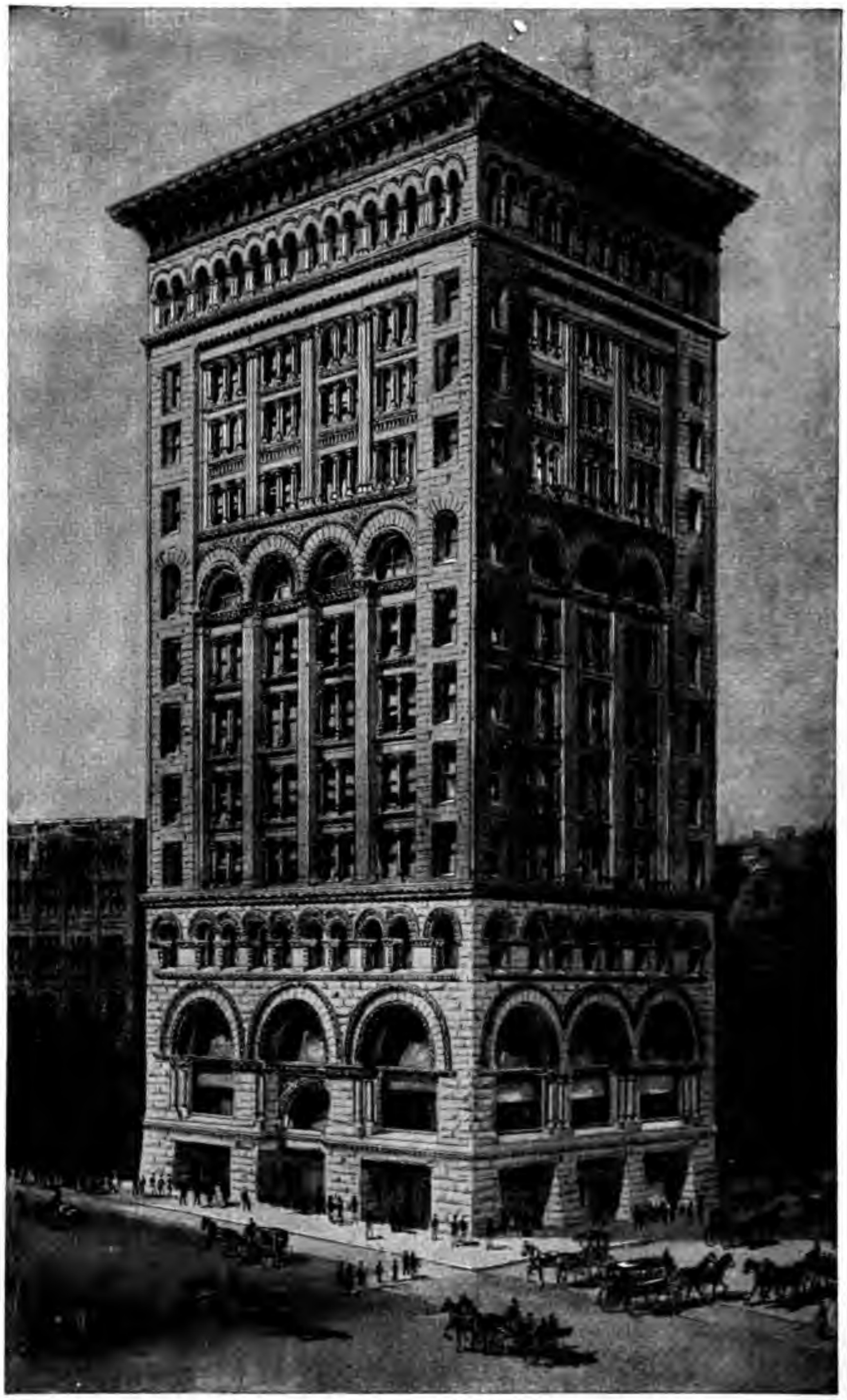
MANHATTAN LIFE INSURANCE CO.'S BUILDING, NEW YORK CITY. BEDFORD STONE.

as first laid down before the structural part has been considered, are strictly adhered to, almost impossible problems may be presented to the designer of the frame, and unnecessary expense incurred. Therefore, the structural engineer, when he finds he is being led into too complicated and expensive construction, should consult the architect, and where possible, without injuring the appearance of the building, the original lines should be changed. This architectural change for the most part would consist of a slight change in design or position of pilasters and cornices and some unimportant angles on the exterior of the building.

As in all masonry, the foundation for the curtain wall is of greatest importance. It seems strange at first sight that no standard construction has been agreed upon for this part of the skeleton construction; but when we consider the short time in which this form of architecture has had to develop, and the fact that most of these frames have been constructed by different engineers, each having his individual ideas in regard to a new form of construction, and the variation in decorated front to be supported, the variety we meet with in this detail is not to be wondered at. A long list of details could be shown of combinations of I beams, channels, Z bars, and angles that are now in use, but since these would be uninteresting to the general reader, and those particularly interested in this form of construction can procure them from books and articles on individual buildings, we will confine ourselves for the present to generalized methods and principles.

Besides carrying the wall, this beam serves as a floor girder to receive the ends of the floor beams, or as a floor beam, and as such receives its part of the floor load, therefore its position must be at a floor level. Its position is also limited between the top of one window and the bottom of the one above. In the horizontal plane its position is very much limited, owing to the fact that its ends are to be connected with the columns.

In regard to the manner of loading this spandrel beam we have first the cornice, or horizontal band of stone ornamentation, which in the architectural design is between the windows and on about the same elevation as the spandrel beam, so we can assume that this work will be fastened directly on the outside of the spandrel beam. From this band to the next band above we have the wall, or rather since the wall is mostly windows, the mullions between the windows. Thus we have two kinds of loading, a uniform loading and a loading at intervals along the beam corresponding to the window spaces. Now neither of these loads are over the center of the web of the beam, but are applied externally by means of supports built to the outside of the beam, and tend to produce a twisting moment in the beam which carried to the columns produce the effect of an eccentric loading there. Where the outside wall is of stone and extends out well from the steel frame this twisting moment is quite an item, and must be balanced by having the floor beams at right angles to the spandrel and attached to it, in this way the structural problem becomes one of the cantilever, the supports for the stone work being a continuation of the floor beams with the spandrel acting as a fulcrum and receiving its load centrally and vertically. For causes of economy, the spandrel beam is generally a deep girder (a plate girder). Now the floor beams instead of ending at this girder can project beyond it, and thus form a shelf on the outside of the structural frame, on which can be built a stone wall of any design. If the spandrel beam can be placed so as



AMES BUILDING, BOSTON. NORTHERN OHIO SANDSTONE.

to receive the floor beams on its top flange the construction is very simple, otherwise it receives the floor beams somewhere on its web and the continuation of the beams are formed by riveting on the outside of the spandrel. It would give a better form of construction if all supports for walls were built as above, but generally if floor beams are perpendicular to the front wall they are parallel to the side walls, and to have the floor beams making right angle connections with all four walls would cause a little complication in construction at the corners of the building. By so doing, however, we are following correct principles of construction and obviating the undesirable twisting that is produced by loading a detached beam on one side. In all structural steel work, except the skeleton of a steel building, all parts of the construction are in view and the steel can be easily examined to see how it is standing usage, and can be constantly repainted as a protection against rust, and when different members show weakness they can be replaced. But when once the steel of a building is covered with masonry it will never see the light of day again, except in the case of fire or the destruction of the edifice. It is, therefore, very important to be sure that all connections are well made and the steel well coated with paint, and that the stone covering is so constructed as not to allow moisture to attack the steel. It is one of the great faults in this form of construction that the structural material and details cannot be inspected, and considering this fact it is surprising to see with what carelessness these frames are often put together.

After the steel work has been erected and the architect is absolutely certain he has a structure that will stand rigidly all strains produced by loads and wind, the next work to be taken up is the construction of the outside walls. Before the mason starts his work it is well to see that all spandrel beams are in their correct positions, and that the stone work as designed will fit into its place between beams and columns. When everything fits as designed, the methods of constructing a curtain wall will be the same as those employed in erecting a wall in any other position.

The artistic part of the problem, however, is different from anything ever attempted before, and it is in the design of the front wall that the architect expends his best efforts and brings into play his entire knowledge of architectural adornment.

The architect's first aim seems to be to hide all the structural steel work and give the front of his building the appearance of one solid wall of masonry; then he turns his attention to adornment, and we have presented to our view, in cities where high buildings thrive, all manner of walls, from the rigorously plain to the one on whose face every architectural adornment ever conceived finds a resting place. At first sight some of these fronts may please and awe by their striking appearance, but if we see more of even the finest, we admire it less and look upon it as a most unnatural stone wall, and a feeling that a fraud has been perpetrated grows upon us. The use of steel in the structural part of architecture has produced a revolution, but into architecture as an art it has not entered. True, architecture is an adornment of the materials of construction, and since our ideas of architecture are gotten from a time when the use of steel was not known, we associate all architectural effects with the materials used in former times. But now, however, since steel is playing such a part as an architectural material of construction, the time is sure to come when the art will recognize it, and

THE MAJESTIC, INDIANAPOLIS, IND. BEDFORD STONE.

not until that time can we hope for pleasing architectural effects in steel construction.

When the front of a skeleton constructed building can be so designed that each curtain wall of stone will show to the untrained eye that it is merely a covering for an open space between two floor beams and two columns, and the fact that the steel frame is carrying the wall made evident, it will then be that the art of architecture is adapting itself to this form of construction. It is not necessary that the building front should be marred by unsightly beams and columns. They may be entirely covered, but yet have the covering so arranged as to suggest what is behind. And then, again, we may have the beams and columns in full view, ornate, and enframing the individual walls of stone, with the stone and steel blending artistically, presenting to view strength and architectural grandeur. When and how such combinations will be made the future alone can reveal. We can rest assured, however, since stone or other non-metalic materials are non-conductors of heat, that they will always find their place in the curtain walls, and that the structural designs of our tall buildings, as they are at present, are too near the ideal to be much improved upon. The architect has shown his ability as a selector of materials and as a constructor. The problem before him now is to adorn his construction, not to hide it.

E. McL. Long, C. E.

BRIDGES IN INDIA.

WHILE it is generally known that there are extensive bridge structures in India, there has been comparatively little published regarding them in this country. The famous Sukkur bridge was widely illustrated and much was published concerning it. The 820 feet span was the longest railway span in the world until the completion of the Forth bridge. Mr. F. E. Robertson, the engineer, is the son of a country gentleman and was educated at a private school. He learned engineering as an articled pupil to the resident engineer on the railway extension works from Victoria Station.

At the end of 1868 he entered the Indian P. W. D. by open competition and performed the usual duties of an engineer on the survey and con-

F. E. ROBERTSON.

struction of state railways until 1877. He then took two years' furlough, which he spent as one of the inspectors of the India office for state railway material and stores. In 1879 he rejoined the Indus Valley State Railway and introduced the wagon ferry by which the traffic was successfully carried over the Indus until the bridge was built.

In 1899 he was appointed engineer in chief, frontier railways, including the Khojak Tunnel, and at the end of that year left government service for the East Indian Railway.

He has now been appointed President of the Egyptian Railway Board, which consists of three members—an Englishman, a Frenchman and an Egyptian to represent the different interests, and will doubtless, in his new

position, realize the expectations formed of him from the knowledge and foresight he has displayed on the large engineering works both under construction or control in India. There can be no question that he was at the head of the profession in India. In the theory and practice of engineering he stood alone in this country, and the India office was not backward, we are glad to say, to recognize this, as evinced in his present selection for a high post in Egypt, in making which Lord Salisbury was well advised in his choice.

Mr. Robertson is a hard student, as well as a working man. The Lansdowne bridge will be a monument to his skill and ingenuity.

This brief biography is taken from a recent issue of Indian Engineering, from which also we have gathered the following items about recent bridge structures. The viaduct illustrated in Fig. 2 is on division 9 of the Assam-Bengal Railway and it is on 10 deg. curve, radius-573 feet, with a roadway having a rise of 1 in 43. It spans a small stream, and may be considered more as a viaduct than a bridge to allow water to pass. Owing to its great height it was found necessary to use a 100 feet span on trestles 80 feet high in the center. This arrangement, with the minor side spans adopted, came out as the most economical after comparison with other spans. There is plenty of good building stone near the site, and the masonry piers consist of sandstone set in lime mortar. The estimated cost of the work is Rs. 106,938, detailed in the subjoined abstract:

Quantities.	Sub-heads.	Rate. Rs.	Per	Total. Rs.
28,785 c. ft.	1. Excavation in foundations	70	1,000	2,015
8,315 "	2. Concrete in foundations	45	100	3,742
11,473 "	3. Masonry in foundations	75	100	8,605
38,925 "	(a) Masonry above foundations	75	100	29,194
460 "	4. Ashlar in copings	100	100	460
253 "	5. Bed stones	2	C. ft.	506
726 "	6. Woodwork	3/8	C. ft.	2,541
48.78 tons.	7. Ironwork in trestles	285	Ton.	13,902
3 "	(7a) Cast iron in ballast plates	200	"	600
120.58 "	8. Ironwork in girders	235	"	28,336
120.58 "	9. Erecting and painting	55	"	6,632
17.92 cwt.	10. Petty ironwork	24	Cwt.	430
4.96 "	11. Corrugated iron	15	"	74
630 c. ft.	12. Hand railing	3	C. ft.	1,890
2,200 sq. ft.	13. Stone pitching	25	100 s. ft.	550
				99,477
	2½ per cent. for tools and plant	--	----	2,487
	5 " contingencies	--	----	4,974
	Total	--	----	106,938

English, Rs.	34,872	
Indian, Rs.	72,066	
Total		106,938
Stores, Rs.	42,454	
Cash, Rs.	64,484	
Total		106,938

The 16th division of the same road extends from mile 412 to 471 and is under the charge of Mr. F. Grove, executive engineer. From mile 471 to the Daiung River (mile 449) it passes through fairly open country and the work on this portion is moderately heavy. The country is very wet, and,

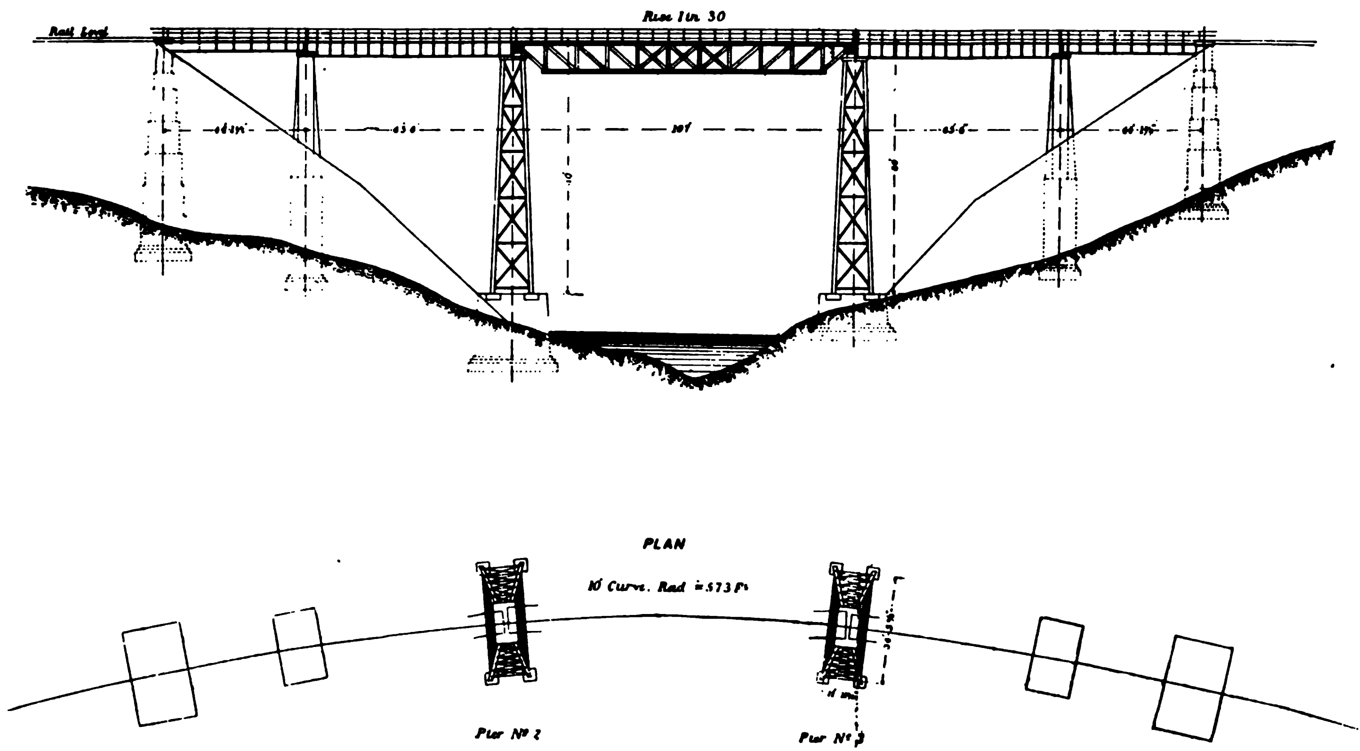


FIG. 2.—ASSAM-BENGAL RAILWAY BRIDGE NO. 49.

as in the case of the 17th division, the season during which work can be done is very short. Work has gone on for two full seasons, but the division has never, until this year, attracted a sufficient labor force, with the result that some work still remains to be done before rails can be laid from Titabar to the Daiung River. Some six miles of rails have been laid, and it is confidently expected that with a diversion at the Kakodanga River railhead will shortly reach the Daiung River, and thus enable the girders for this bridge to be brought to the site and erected. From the Daiung River to the southern end of the division at Dimapur (37 miles), the line runs through the Nambor forest, and as contractors and coolies alike do not care for work on this portion in consequence of the great amount of sickness, very little progress has been made; the work, however, is light, and as there is a much larger labor force on the division this year, it is hoped that it will be pushed forward to completion during the present working season. The only bridges of importance on the division are those over the Daiung and Dhansiri, the former consisting of nine spans of 60 feet and the latter four spans of 60 feet on well foundations. The work on these is in hand, and when the rails can pass over these bridges they should go forward to Dimapur without any check.

It is understood that the portion of the Gauhati branch—112 miles from Gauhati to Jamuna Mukh (75 miles), which was closed on account of the earthquake—cannot be opened at present, as one of the bridges on this length has been damaged so much as to render the provision of temporary means of crossing the river necessary. This is the bridge over the Titaimari (one 100 and two 40 feet spans), which is to be entirely rebuilt. It is hoped that the foundations, or part of them, will be found fit to be used on the new bridge. The Kopili bridge (eighteen 60 feet spans and three 100 feet spans) is to be overhauled; three piers were shaken and cracked low down, one of them rather badly, and this pier is to be closely watched and the whole bridge overhauled during the cold season. The work on this branch is to be taken in hand vigorously during the present working season, and already large batches of coolies are arriving at Gauhati for the work on the branch and the divisions northward. A special effort is to be made to push forward the work to Lumding so as to render it possible to reach the divisions of the Hill section from Gauhati, and thus enable the work on that section to be pushed forward to completion.

Work in other localities is much of it of an extensive character. The Sone bridge, Dehri, over the Sone River, 93 spans of 100 feet each, will not be finished for some time to come, though the foundations for 60 piers are in hand and the wells for 30 piers have been sunk. But the opening of the line will not be delayed on account of the bridge, as the rails will be carried over the river bed by a diversion. It has been, we hear, decided to build the piers of the Sone bridge on the wells in which clay has been found at a depth of about 18 feet, and there will be consequently a large saving of masonry work on this bridge—not, we hope, at the expense of safety! Work on this undertaking, January, 1899, is not going on so rapidly as it should, and by the time the working season closes more than about one-fourth of the entire work on the bridge will remain to be done next year.

The Gogra bridge, Bahramghat, will link the Bengal and Northwestern Railway Trans-Gogra System with other lines, broad and narrow gauge,

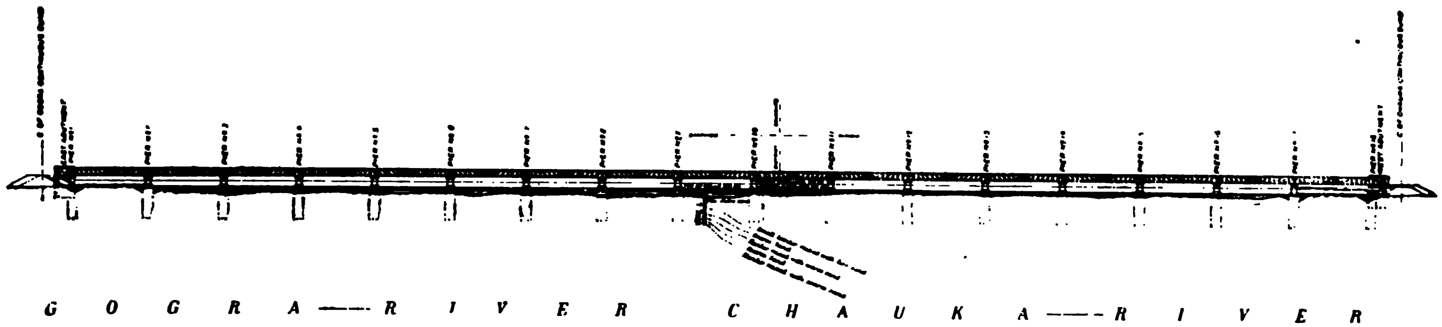


FIG. 3.—GOGRA BRDIGE. GENERAL ELEVATION.

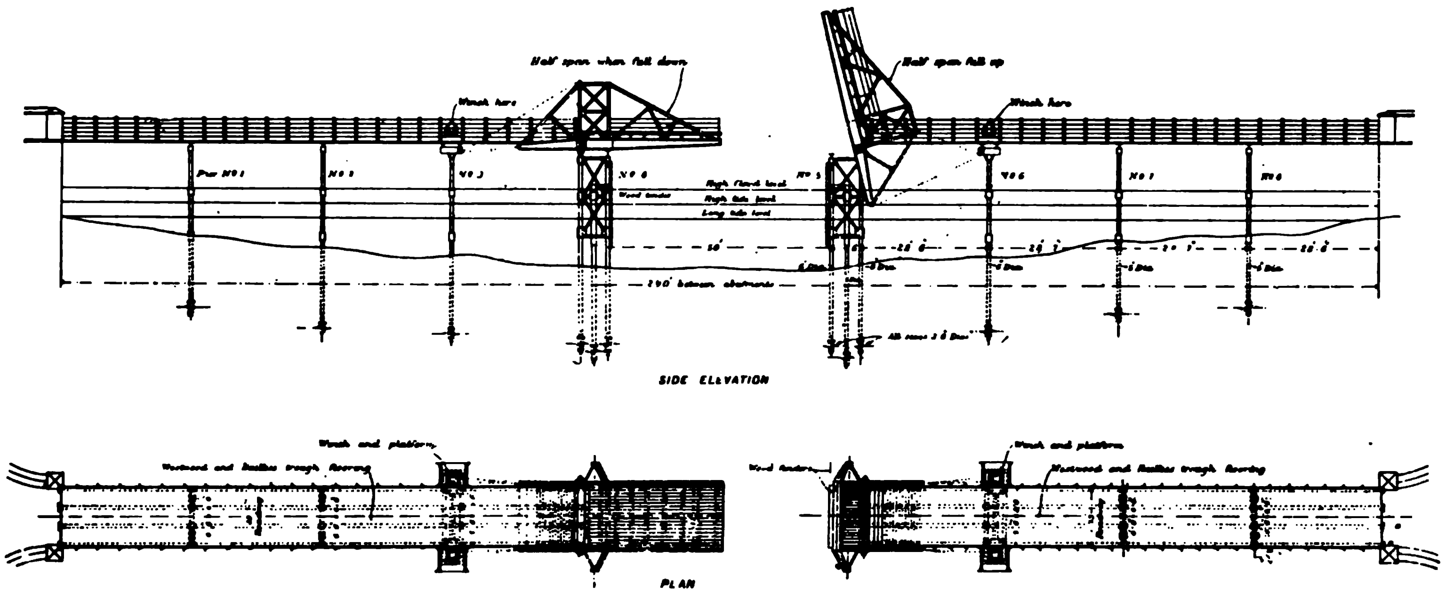


FIG. 5.—SCREW PILE BRIDGE. CORINGA. GODAVERI DISTRICT.

to the south and west. We gave a sketch of the training works so admirably designed to keep the river in the desired course—the site plan showing the magnitude of the operations in that respect. The bridge consists of 17 spans of steel girders of 200 feet on the clear. This structure was formally opened and named the "Elgin Bridge." Mr. W. J. Turnbull has been the resident engineer in charge of the construction.

Sir Antony McDonnell, in the presence of a large number of specially invited guests and all the officials of the Bengal and Northwestern Railway, opened it on January 25th by driving a spike in the west abutment. The guests re-trained, and went over the bridge, 3,695 feet long, to Gogra Ghat, where breakfast was served under a special shamiana.

The project for joining up the Bengal and Northwestern railway lines

FIG. 4.—KALIMACHAK BRIDGE, G. I. P. R. R.

north of the Ganges with those in Central and Western India, has long been under discussion, and the construction of the bridge over the Gogra and Chanka rivers, near Bahramghat, forms the main part of the scheme.

The Gogra, like most of the large rivers in Northern India, has hadly defined banks, and in high floods inundates large tracts of country, and its main channel is always changing. In recent years this channel has been steadily moving toward the east at the rate of about 600 feet per year.

The floors rise 15 feet above ordinary summer water level, and while they last there must be great scour in the bed of the river, as in November, after the floods have gone down, the main channel for 300 or 400 feet in width is about 24 feet deep, and during the hot season about 15 feet deep. The bed and banks, which are, or were, four miles apart, consist of sand.

Borings 100 feet in depth have been taken at different points along the

line of the proposed bridge, and nothing but sand has been met with. The bridge has, therefore, to be protected by training bunds and spurs, and this is being done after the manner which has been found so effectual in dealing with the bridges over the large rivers in the Punjab.

In the main channels of the river, where the current is strong, it is be-

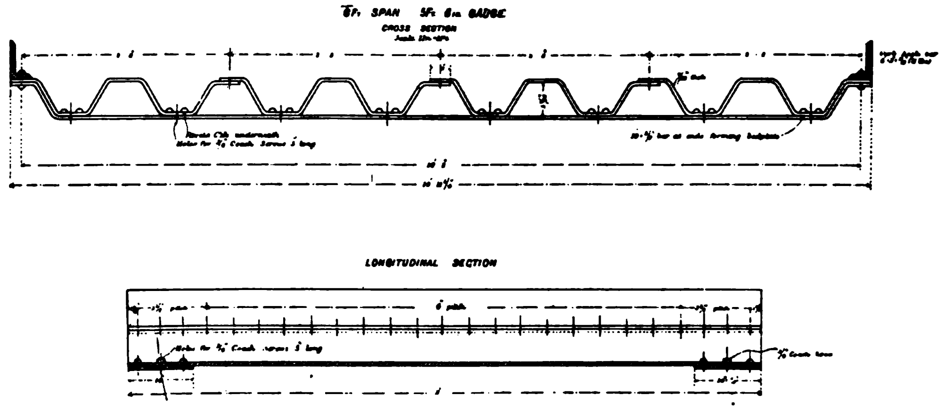


FIG. 6.

lieved that the bed for a considerable depth must be in motion, so that a section of the river taken in the dry season, when the currents in the

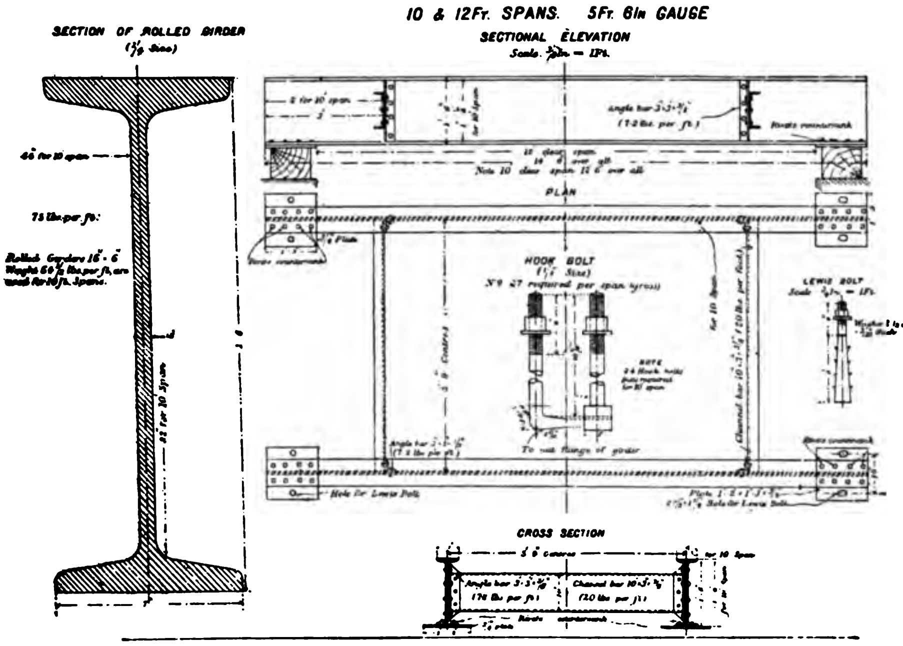


FIG. 7.

channels are weak, does not represent the section when the river is in flood and the current strong.

In the present case calculations for the discharge of the two rivers have

been based on the assumption that in high floods, 10 to 20 feet of the beds of the rivers are in motion.

The hydraulic mean depth thus arrived at is 33.22 feet.

The declivity of the bed may be taken as 1 in 5,000, and the average velocity 6 feet per second; the total discharge thus found then equals 872,897 cubic feet per second.

The cost of the bridge, with the protective works, including the cost of upward of 60 lakhs of cubic feet of block kunker, is estimated to be Rs. 2,843,891, and the cost of the approaches, with two stations, is estimated to be Rs. 221,234, making the total cost of the work Rs. 3,065,125.

The masonry of the piers is of brickwork with heavy ashlar bed-blocks and capping. The block-house abutments are built on eight small wells and flanked by circular towers, loop holes, etc., for defensive purposes.

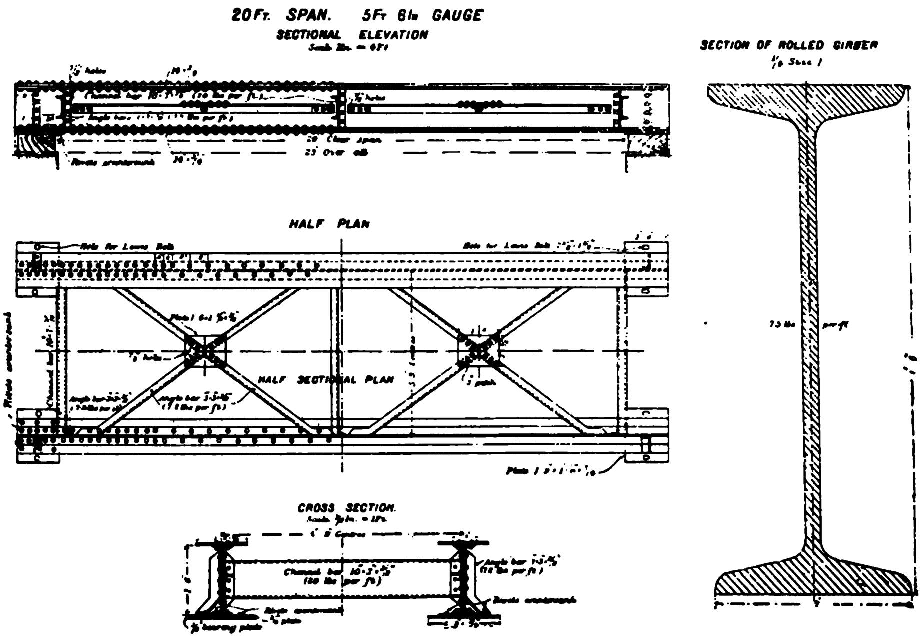


FIG. 8.

The work on the Kosi bridge, on the Hajipur-Katihar extension of the Bengal and Northwestern Railway in January, was being pushed on vigorously. The bridge is made of 15 spans of 200 feet girder. Mr. Addis, district engineer, is in charge of the construction of this bridge under Mr. Izat's sound supervision. Arrangements have been made for the carriage of the English materials for this bridge by the Eastern Bengal State Railway.

The Great Indian Railway has numerous interesting structures, one of which is shown in Fig. 4. The spans of the Kalimnachak bridge are 109 feet center to center of pillars, and the present superstructure was substituted a few years ago for a plate girder bridge of obsolete design. The intermediate pillars on each pier have nothing to do with the present bridge having carried the middle girder of the old bridge.

The material and workmanship in the bridge were the very best that

could be obtained. The design, by Sir George Bruce, P.P Inst. C E., leaves nothing to be desired on the score of efficiency or economy. We gather that many similar bridges are in existence on the Great Indian Railway.

We have been permitted to see the drawings of the Indian Midland Railway bridges erected some twelve years ago, and a similar standard to the

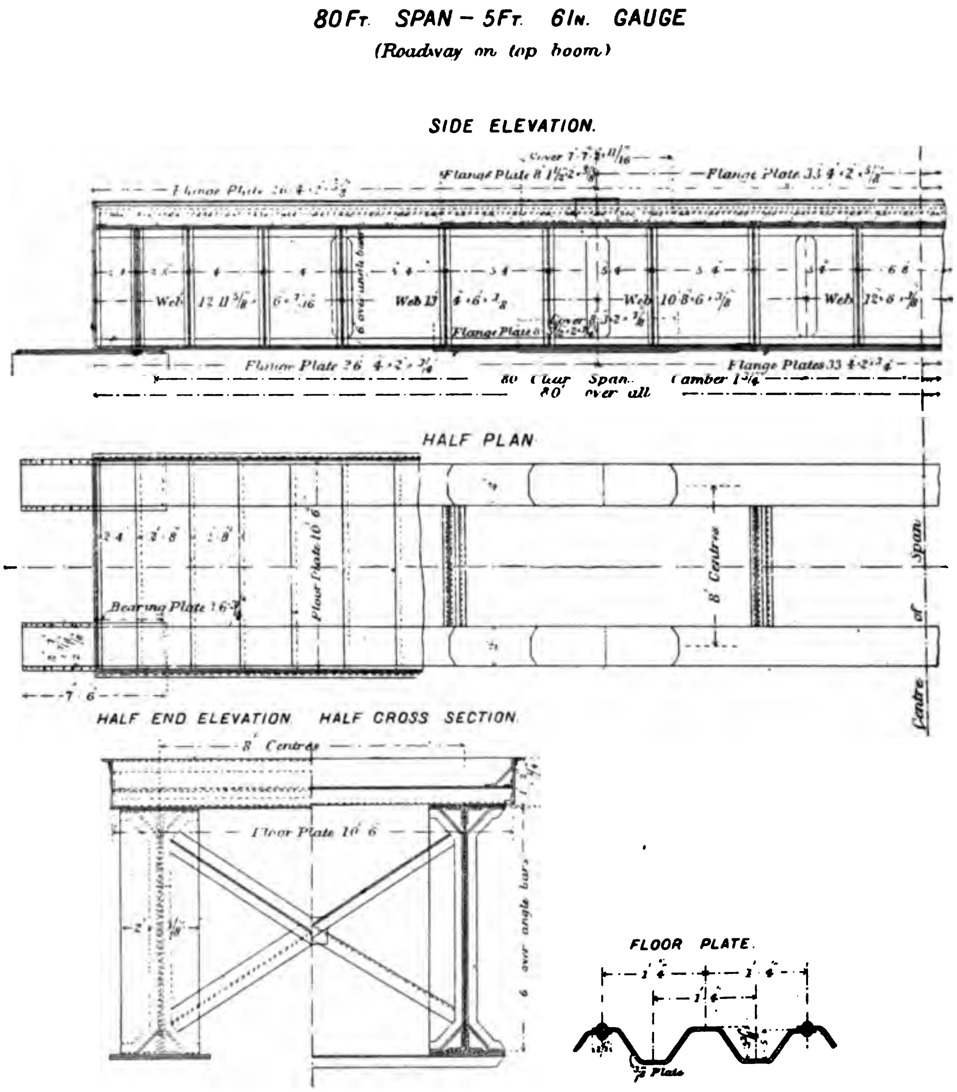


FIG. 6.

above was followed. This, too, will be found to be the case on other Indian Peninsula railways.

The annexed plate, Fig. 5, shows the general arrangement of the screw pile bridge at Coringa, the most notable feature in which is the opening span of 50 feet. Each bascule is accurately balanced, and the bearings are so well arranged that when full loaded the bascule is readily turned by the aid of four

coolies without the use of the capstans. The winches have been supplied of a heavy make to tackle any sudden shocks. When the spans are lowered in position, they are securely locked by powerful bolts controlled by levers on the bridge platform. The total length of the bridge is 290 feet and the

80 FT. SPAN – 5 FT. 6 IN. GAUGE

(Roadway on bottom boom)

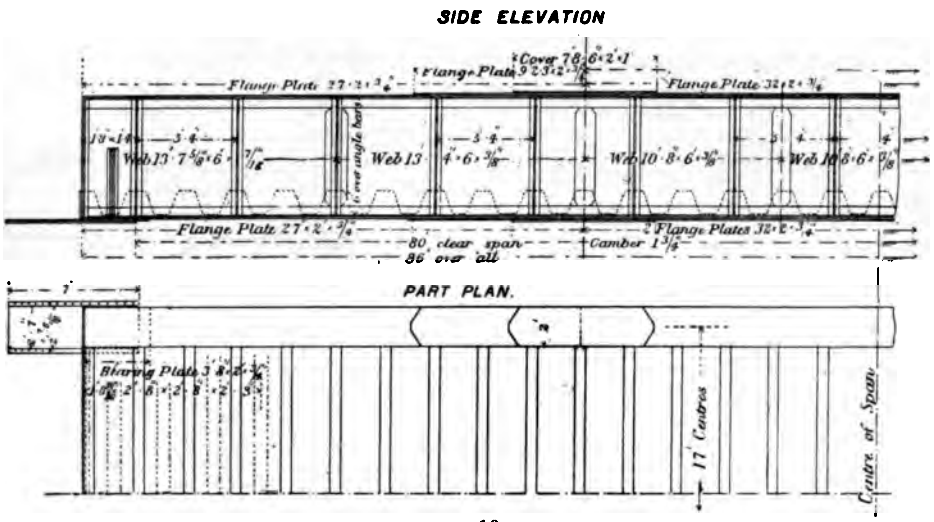


FIG. 10.

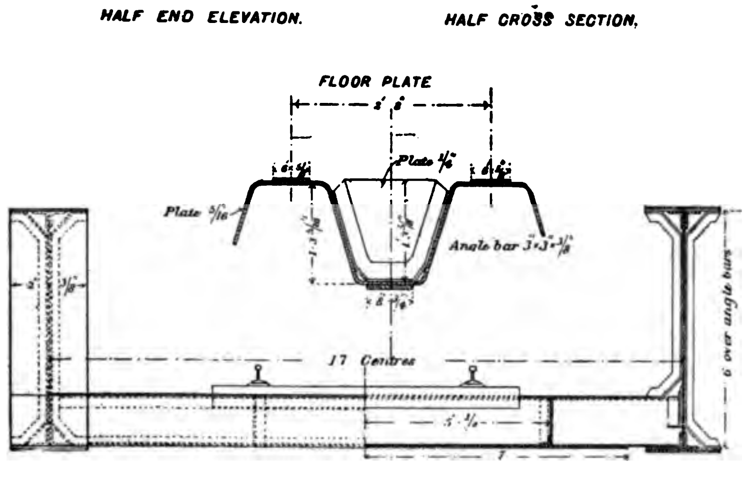


FIG. 10a.

roadway is 13 feet clear throughout. All the beams are of Glengarnock Steel and the flooring is of Westwood and Baillie's steel troughs. The piles are of solid wrought iron fitted with cast iron screws of large diameter, and the bracing is of steel.

Messrs. Burn & Co., Howrah, were entrusted with the execution of the order by Mr. P. H. Brown, M.I.C.E., District Board Engineer, Godaveri, and have carried it out in their usual thorough manner.

It may be added that the locality, Coringa, is a place on the road from Coconada to the French settlement of Yunam, which road will ultimately go through several villages and to Dacharam, a large market—opening out a large tract of country not get-at-able by carts at all. The reason of the opening in the bridge is that the docks at Coringa cannot be placed below the bridge as the banks are unsuitable, neither can the bridge be conveniently placed above the docks as there are several big channels in addition to the main river to be crossed and the cost would be greater.

Although the port of Coringa is not what it was, still numbers of ships

100 FT. SPAN – 5 FT. 6 IN. GAUGE

(Roadway on top boom)

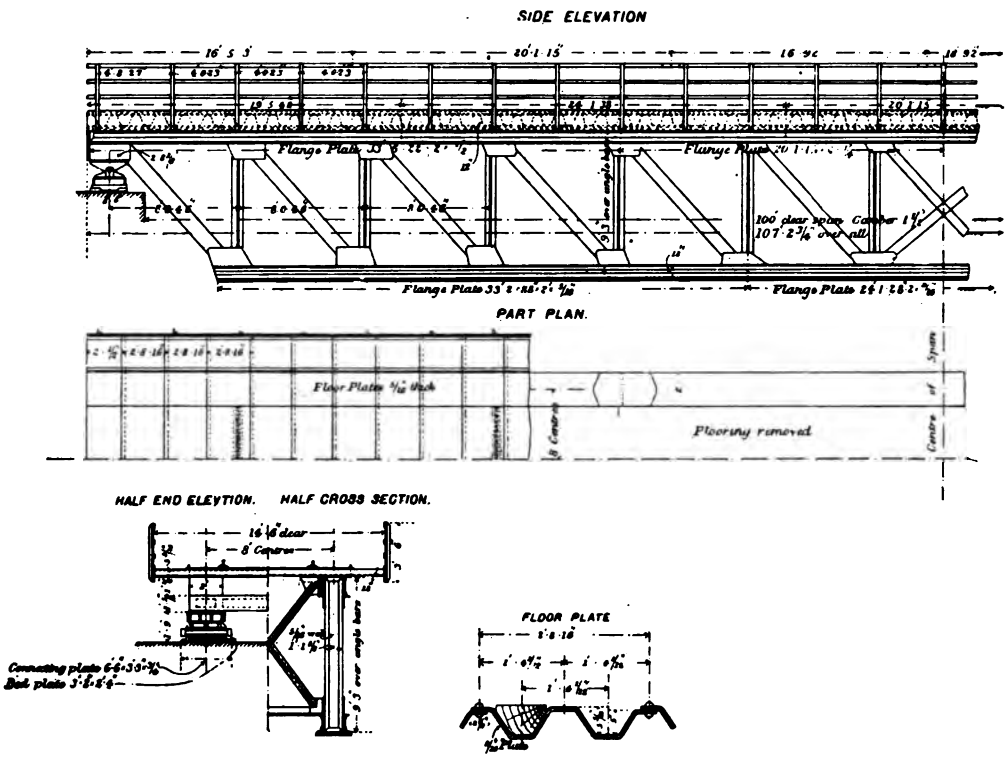


FIG. 11.

go there for repairs, and ships are also built there. A three-masted ship of 600 tons has just been renovated there in a manner that proves that there are still latent resources in many but little known parts of the country.

The cost of the bridge is Rs. 60,000, the iron work absorbing Rs. 40,000.

The work on the Godaveri bridge on the East Coast Railway is being done under Mr. Walton, Engineer-in-Chief, a bridge expert. The Benares bridge on the O. R. R. is a standing monument of his professional skill, and the appointment of this officer to its charge is the highest guarantee of the important bridge under construction being completed in the most efficient and economical manner. The bridge is of 56 spans of 150 feet girders; one

span of 49 feet girders has since been added to secure increased stability. The estimated cost is about Rs. 5,970,000.

The Gokteik Gorge viaduct in Burma on the Mandalay-Salween Railway, has been sanctioned. The viaduct will be 2,110 feet long and 325 feet high, and the approaches will be through tunnels 1,760 feet long. The cost of the viaduct is estimated at sixteen lakhs, and that of the tunnels at six lakhs. The whole bridge with its approaches is estimated to cost 31½ lakhs of rupees. The work will occupy altogether about three years.

The recently adopted standards for the Indian State Railways are shown in Figs. 6 to 11. The particulars of the spans being given below:

6 FEET CLEAR SPAN.

	Weights Tons	cwt.	qrs.	lbs.
Girders	1	6	2	0
Bolts, nuts, and washers	0	0	0	14
Service bolts, nuts, and washers	0	0	1	14
Weight of one span complete	1	7	0	0

Price in November, 1895, £10-19-4.

Notes.—The depth of ballast between top of trough plate and bottom of sleeper should not exceed about 3 inches, and a ballast wall should be carried up to the level of top of trough plate.

The trough plate should be laid on timber bedplates 10 feet by 10 inches by 5 inches.

All rivets to be put in in India. All rivet holes to be ¾-inch diameter.

10 FEET CLEAR SPAN.

	Weights Tons	cwt.	qrs.	lbs.
Girders	0	18	2	14
Hook bolts (No. 27)	0	0	3	21
Lewis bolts (No. 9)	0	0	2	7
Service bolts, nuts, and washers	0	0	0	14
Weight of one span complete	1	0	1	0

Price in November, 1895, £8-12-2.

12 FEET CLEAR SPAN.

	Weights Tons	cwt.	qrs.	lbs.
Girders	1	3	3	0
Hook bolts (No. 27)	0	0	3	21
Lewis bolts (No. 9)	0	0	2	7
Service bolts, nuts, and washers	0	0	0	14
Weight of one span complete	1	5	1	14

Price in November, 1895, £11-5-3.

Note.—Holes tinted black in drawing to be riveted in India, except those marked countersunk. All rivet holes to be ⅞-inch diameter. The whole of the work is steel.

Dimensions of both spans are similar, except those shown to the contrary.

20 FEET CLEAR SPAN.

	Weights Tons	cwt.	qrs.	lbs.
Girders	3	13	0	0
Hook bolts (No. 44)	0	1	2	0
Lewis bolts (No. 9)	0	0	2	7
Service bolts, nuts, and washers	0	0	1	14
Weight of one span complete	3	15	1	21

Price in November, 1895, £33-9-6.

Note.—Holes tinted black in drawing to be riveted in India, except those marked countersunk. All rivet holes to be 1 inch diameter, except those in angle bars which are ⅞-inch. The whole of the work is steel.

(1) 80 feet clear span, rails above with trough floor.
(2) 80 feet clear span, rails between with trough floor.
(3) 100 feet clear span, rails above with corrugated floor.

The details of (1) that is, the 80 feet span with roadway on top boom are as under:

	Tons	cwt.	qrs.	lbs.
Girders	51	13	2	19
Lewis bolts (No. 18)	0	1	0	9
Service bolts, nuts, and washers	0	3	0	0
Weight of one span complete	51	17	3	0

Price in February, 1898, £638-13-4.

The details of (2), that is, the 80 feet span with roading on bottom boom are as under:

	Weights			
	Tons	cwt.	qrs.	lbs.
Girders	63	11	3	0
Lewis bolts (No. 13)	0	0	3	3
Service bolts, nuts, and washers	0	4	2	0
Weight of one span complete	63	17	0	3

Price in October, 1893, £768-10-6.

The details of (3), that is, the 100 feet span with roadway on top boom are as under:

	Weights			
	Tons	cwt.	qrs.	lbs.
Girders, including saddles, rollers, etc	71	10	1	14
Bolts and washers for saddles, turned (No. 26)	0	0	3	0
Bolts and washers, roller frames, turned (No. 18)	0	0	2	0
Sleeper bolts (No. 348)	0	8	0	7
Lewis bolts (No. 18)	0	1	2	14
Service bolts, nuts, and washers	0	6	0	0
Weight of one span complete	72	7	1	7

Price in February, 1896, £682-15-0.

The drawings have been compiled from the India Office Contract Drawings.

The specifications for bridges issued by the Government of India, Finance and Commerce Department, last year, are given in full under the head of Timely Topics.

CONCRETE IN RAILWAY BRIDGE CONSTRUCTION.

NOT every great railroad is fortunate enough to have good stone for bridge masonry on its lines. This is specially true in the middle and southern portion of the Mississippi Valley. There the available quarries are widely scattered, and the long haul adds so much to the cost of cut-stone masonry as to make it nearly prohibitory, resulting in the indefinite renewal of timber structures and giving such a temporary character to mile after mile of otherwise well-built railroad. But, while the quarries that can produce well-bedded building stone are rare, there are many which yield a tough and durable stone suitable for ballast, and it requires but the addition of sand and cement to such material to form an acceptable substitute for cut stone. Within the past four or five years the railroad engineer has sought, by means of this kind of masonry, or concrete, to replace the timber and pile structures which have so long been a nightmare in his dreams of permanent construction; and, to meet him at least half-way, Portland cement manufactories have been multiplied so rapidly that now he is able

FIG. 1.—TWO SEMI-CIRCULAR ARCHES, EACH 40′ SPAN; TOTAL LENGTH OF MASONRY 160′; BUILT IN SANDSTONE, LIMESTONE COPINGS.

to build structures at far less expense and with a prospect of greater endurance than could be expected of the rough, dry masonry so often used thirty or forty years ago. It is not intended as a disparagement of the engineering skill of the distinguished engineers who built the Illinois Central Railroad to speak with apparent criticism of the work they planned and executed.

The conditions under which that work was done are not fully appreciable at this late day, and it is no discredit to them to say that their masonry has to be rebuilt, and their arches and culverts have to be renewed or strengthened. Doubtless they were limited to the use of such stone as was easily obtainable, and perhaps its character had not been proved by long continued use in the comparatively new country through which the road was built. Sandstone, in particular, has weathered badly. In one case a structure consisting of two semicircular arches of forty feet span, supported by a central pier and two abutments and spanning a ravine about one hundred and sixty feet long and forty feet deep, the arches and supports of sandstone and the copings and upper courses of limestone, was getting into an alarming con-

FIG. 2.—TWO 40′ SEMI-CIRCULAR ARCHES, REINFORCED WITH CONCRETE—LITTLE MUDDY RIVER.

dition, largely due, however, to the careless way in which water had been discharged from tank cars standing on the bridge into the stream below, which had been converted into a reservoir by a dam under the arches. The space between the spandrel walls was hollow, and had originally been covered and made tight by the coping courses. The breaking of some of these permitted the water to penetrate to the voussoirs and spandrels, and the action of frost was gradually destroying the masonry, a number of the spandrel stones and some of the arch ring stones being broken and in danger of falling from the walls. To construct new masonry would have been very expensive on account of the complication of keeping the road in operation during the work, and to replace the masonry with an iron structure seemed at first the only alternative. The larger part of the work being in fair condition, it was finally thought a justifiable experiment to reinforce the work with concrete, lining the arches and facing the walls with from eight to nine inches of this material, and making an entirely new covering to the

whole structure in place of the limestone coping courses, which were the most badly damaged portions of the work. The reinforcing material was carried down below the action of frost, or to the rock or shale foundation on which the original masonry was built, and was made of fine crushed stone, sand and cement in rich proportions of the latter ingredient. It was built inside molds anchored to the stone work, these anchors being so made that the outer ends could be unscrewed from the rest, leaving the inner portion to assist in tying the concrete work to the original masonry, none of the iron coming within an inch or more of the finished surfaces. The old coping courses were removed, section by section, and a series of transverse I beams were set at a uniform level on the old stone work, between which concrete arches were built and along the outer ends of which parapet walls

FIG. 3—12′ ARCH, BUILT INSIDE OF 40′ SEMI-CIRCULAR ARCH—ASH CREEK, NEAR RAMSEY, ILL.

were raised. Between these crushed stone ballast was placed, and the track was laid thereon as on any ordinary embankment. Drains were put through this parapet wall at regular intervals and the surface of the concrete work was sloped to these, so that no water could possibly accumulate in the ballast. Accompanying illustrations (Figs. 1 and 2) show the above work, both before and after the concrete was applied, and while, to the trained eye the masonry of the original structure is the more sightly, there is in the appearance of the other a satisfactory look of strength, and the knowledge that the work has stood the exposure of two winters without showing any defects goes far to compensate for any esthetic quality lacking in the later view.

At another arch on the old main line of the road, between Centralia and Freeport, the effects of age and weather had progressed so far that it was necessary eight or ten years ago to put in a temporary trestle work astride the original masonry to carry the track. When this had become too old for safety, taking advantage of the fact that the whole area of the old arch was

not needed for a waterway, an entirely new concrete arch of smaller dimensions was built inside the old one, as shown by illustration (Fig. No. 3). When this had fully set earth filling was carefully placed and tamped around the concrete, the old arch was dropped and left as a part of the filling, and the embankment was raised and widened to the standard section.

A somewhat different case is shown in Fig. 4. An abutment supporting the south end of the bridge over the Kankakee River was cracking open and bulging out in a very objectionable way; one wing was tearing away from the body of the masonry and was likely to tip over into the adjacent roadway, and the stone of which the whole was built was laminating and crumbling badly. After removing the worst of the old masonry, the track being first supported by piles and timber bents, the whole face of the abutment, including both wings, was treated to a coating of concrete eighteen inches thick at the base, reducing down to about twelve inches at the top,

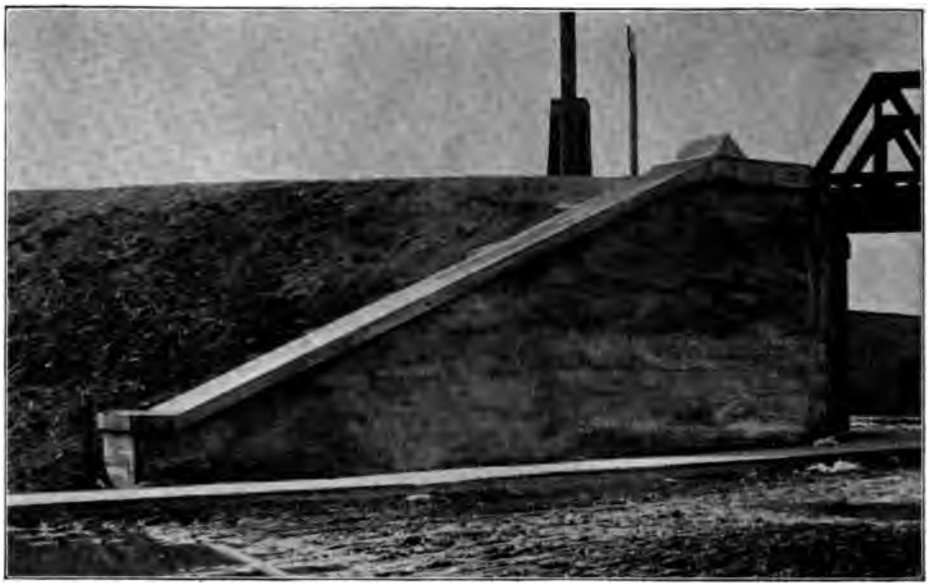


FIG. 4—SOUTH ABUTMENT BRIDGE ON KANKAKEE RIVER, REINFORCED WITH CONCRETE.

the footing being carried well down into the ground in front and the upper work being completed by new copings on the wings and a new bridge seat and parapet, and the whole made more safe by extending the concrete covering about two feet below the surface of the filling on the back of the masonry. In this case, on account of the bad character of the stone itself, the concrete was needed to protect the old work from the weather, as well as for additional strength and enlarged section of the abutment. The union of the new and old work was further secured by cutting out portions of the old face work, making recesses, into which the concrete was bonded as the same was built up.

A twelve-foot brick arch culvert was built under an embankment about thirty feet high, near Baton Rouge, La., the material of which the embankment and the whole adjacent country was made being a clayey soil, which

was easily saturated with water and was likely to slip when wet. This bank and culvert have for years been the cause of almost constant trouble. One of the wings of the latter was overturned, another cracked, and the culvert began to tear apart, while the bench walls under the arch threatened to squeeze together, although there was a foundation of piles, with a timber grillage under the arch. The plentiful rains of that region often fill the opening half full of water and keep a constant stream running, which was no easy opponent in handling the repair work. A dam was built above the arch, and a wooden flume was constructed sufficient in size to handle the water at low stages of the stream, and it was planned to lengthen the arch, build out straight wings on the extension, undermine the old foundation and build a new one of concrete to supplement it and to tie same to the new work,

FIG. 5—12′ ARCH AT MONTECINO BAYOU, LA., Y. & M. V. R. R. BANK 35′ HIGH, LINED WITH CONCRETE AND LENGTHENED.

and in connection with this to build an arched invert, in which should be embedded a network of old rails to give the strength required to resist the crushing and tearing strains produced by the clay filling. To add a little to the complications, the Mississippi River is a close neighbor and entirely submerges the culvert at high water and stops the work at a medium stage. The work has been in progress for about sixteen months and is now stopped by the high stage of the Mississippi, but it has progressed far enough to warrant the belief that the remedy will prove effectual as far as the strength of the work is concerned, and the question of making a bank that will not

slide can then be taken up by itself. Here, as in a former case, the new work is being bonded to the old by cutting out at least one-fourth of the face of the old brick work to a depth of six or eight inches, and also by using anchor bolts in parts of the work where forms are placed to confine the concrete to the desired section on the bench walls and under the arch ring. Fig. 5 shows the work in an incomplete stage, part of the net work of rails being riveted up in the bottom of the culvert, part of the mold in place for the new wing, the old brick wing on the opposite side stripped of its copings, and the coping removed from the old head wall. Since the date of this view the work has been practically completed at this end of the arch, and the other end is in a similar unfinished state.

FIG. 6.—SOLDIER CREEK BRIDGE, NEAR FORT DODGE, IOWA. ABUTMENTS EACH 45′ LONG, REINFORCED WITH CONCRETE. NEW BRIDGE SEATS.

There are many bridges on the Illinois Central system where masonry abutments were constructed with long T walls extending up the natural slopes, or built to carry the tracks over artificial slopes at the ends of embankments. These T walls are generally only eight feet thick, are often of poor stone, and were usually widened out at the top by projecting courses forming parts of the copings. As these structures are renewed the general plan is used of substituting concrete for the coping courses, building heavy I beams, spaced two to three feet apart, into the concrete to carry parapet walls spaced fourteen feet out to out, between which parapets ordinary ties are laid on stone ballast to carry the track. Sometimes the

sides of these T walls need a protection of concrete, and sometimes new deck plate girder spans are put in to replace old Howe trusses, reducing the total height of the trusses, and making higher bridge seats necessary. All such work is now done in concrete as shown in the illustration of Soldier Creek bridge, near Fort Dodge, Iowa, Fig. 6, and Dismal Creek bridge, Fig. 7, near Laclede, Ill.

Old stone arches exist in many places where the construction of double track has required an extension of masonry. Concrete here serves the purpose admirably, as illustrated in Fig. 8, where half the arch shown is of concrete and half of stone. Another of these culverts has a sigmental arch, with heavy I beams built into the crown, not, however, in the style of Melan construction, but sufficient to carry the load, and then buried up in concrete as a protection, and also as a further provision for strength, since there is always some doubt to what limmit our wheel loads may go, be-

FIG. 7.—ABUTMENTS DISMAL CREEK, ILL. TOPS REBUILT IN CONCRETE.

fore it may be necessary to rebuild such a structure. Fig. 9 is an end view of this work. In other cases the foundations only of a portion of the culverts are defective, and a new headwall and wings make, as in Fig. 10, a substantial structure. In this case, however, the inside of the arch was lined as a further precaution against disintegration.

But it is not only in the repair of damaged masonry that concrete is useful. It is resorted to for construction of new work where economy is desirable, or where circumstances make stone masonry impracticable. At the Lizard Creek bridge, near Fort Dodge, Iowa (Fig. 11) two abutments and two piers, all on rock foundations, support three sixty-feet deck plate girders, replacing an old A truss and a long trestle work with economy, and to the great improvement of the waterway. At Janesville, Ia., two concrete abutments and one central pier, all on rock foundations, support two through spans of about one hundred and twenty feet each (Fig. 12), and

FIG. 8.—20′ ARCH, NEAR BALCOM, ILL. EXTENDED IN CONCRETE.

furnish a most efficient substitute for five old wooden beam trusses on crib piers, which formerly spanned the Cedar River at that point. The exposed angles of piers and abutments in these two structures are ten or twelve inch I beams, built into the concrete, showing as broad, dark lines on the illustrations.

It often happens that a new railroad line is projected, crossing several old and well established lines, and that it is essential to public safety that grade crossings be avoided. Here concrete construction solves the problem of economy both to the old as well as the new companies, and shortens the time needed to get tracks into operation on the new grades, as could be accomplished by no other means. The crossings of the Chicago, Hammond & Western Railroad under the Illinois Central tracks at Riverdale (Fig. 13) and near Broadview (Fig. 14) are two of several illustrations of masonry built under these conditions. In each case more than one track is provided for both corporations.

Concrete masonry has proved a useful auxiliary in many of the projects of track elevation which are so familiar to the Chicago public. One of those cases where it was preëminently the only thing practicable was in the work of track elevation at the intersection of Clark and Sixteenth streets. A portion only of this work was handled by the Illinois Central organization, namely, raising the draw span of the St. Charles Air Line Companies across the south branch of the Chicago River, in which work the center pier and abutments were made from five to eight feet higher, by using concrete for the additional construction. The work was done at two separate times, and in several sections, the span being held up by blocking on the draw protection in the river until a temporary wooden support could be built under the turn-table, this being subsequently replaced by concrete, built in blocks as portions of the woodwork were removed. The center was about the last thing finished, both abutments and the outer portion of

the center pier, supporting the drum, being first made complete, and the weight being transferred to bearings entirely clear of the center casting. The illustration (Fig. 15) shows the work in progress on the center pier, the concrete being made on a barge adjacent and wheeled up inclines to be delivered at various points as the work progressed. The greater portion of this work was carried on while one track was in use, the draw being turned from time to time as necessary to allow boats to pass through. Traffic was stopped only when actually raising the draw and building temporary supports to hold it at the new elevation. The transfer of weight from the wooden to the permanent structure was managed while the draw was in use, and ready to turn as desired. The second lift of the bridge was necessary to put in the cast blocks needed to tilt it to the grade on which it now stands, and to get a small amount of concrete work finished which could not be done while swinging the span.

Numerous instances similar to the above might be named where concrete construction has proved the economical, expeditious and effective method of repairing old or constructing new masonry. It has a flexibility possessed by nothing else; it can be handled with simple tools, and by comparatively unskilled labor, and, when proper materials are employed, is no less durable than the best masonry, made of cut stone and laid in cement mortar.

How shall work of this kind be secured? A somewhat extended experience has persuaded the writer that the only way to get good concrete is to have it made under the eye of a faithful inspector, who must understand fully what is essential, and who, as well as the contractor and all concerned, must be guided by fully detailed specifications. It is not enough that the contractor be honest in his wish to make good work. The men employed are usually hired at the lowest market rate for common labor, and may never have worked on concrete before. They will pile up a mass of concrete in

FIG. 9.—8′ ARCH, WITH I BEAMS BUILT INTO CROWN.

a foundation, shovel over a small portion of it, ram it a little, and call it "concrete," and feel that they have done well, if, indeed, they form any opinion on the subject. The ingredients of the concrete may be first class, each of its kind, yet it may be poorly mixed, may have too little or two much water, may be of unequal character, here all stone and there all mortar, and may have set a little or a good deal before it is tamped; or it may be put into molds that yield, it may be full of pores on the face or back, or all the way through; it may be built in heaps or mounds, instead of in layers, and it may be rough and unfinished in its general appearance—in short, there are so many things requisite to first-class concrete construction that one should never relax in watchfulness and care in the inspection of any portion of the work.

FIG. 10.—12′ ARCH, NEAR JACKSON, TENN. ENDS REBUILT IN CONCRETE.

The general principles for good concrete may, perhaps, be stated as follows:

1st. The materials should be the best of their kind. The crushed stone should preferably be small, say not over two inches in largest dimension, as large stone are so likely to separate from the mass while being handled in barrows, shoveled, or shot down chutes to the place where the concrete is to be put in. The presence of the smaller chips, and even of stone dust, provided there is no mixture of earthy matter, is not considered injurious, but, on the contrary, usually makes a stronger concrete than if the stone were entirely uniform in size. Probably the strongest concrete can be made of stone of even smaller dimensions than above named, say under one inch in largest dimension, but that would be too expensive to insist on for the ordinary work. For copings and bridge seats such small stone should always be required, as also for such repair work as is done with thin rein-

forcements of concrete, say, under eight or nine inches thick. In ordinary cases limestone will be good material, but for the best work granite makes a stronger union with the cement, and is generally desirable for the thinner kind of work above mentioned.

The sand should be clean and sharp, but not necessarily fine. Coarse sand should be used for the heavier concrete, and it will do no harm if there is a little gravel mixed with it. An ideal concrete might be made by crushing large gravel into pieces which would pass through a two-inch (or smaller) ring, as the angular fragments would bond well with the mortar, but the writer cannot believe that first-rate concrete can be made with the ordinary rounded gravel, containing the usual mixture of large and small stones, as the rounded surfaces must necessarily lack something in stability of bear-

FIG. 11.—LIZARD CREEK BRIDGE, NEAR FORT DODGE, IOWA, I. C. R. R. THREE SPANS, 60′ EACH. ABUTMENTS AND PIERS IN CONCRETE.

ing, and too much dependence would be placed on the mortar. There would also be the tendency before referred to for the large stones to separate from the rest in handling, which is always undesirable. For the finer work, fine, but clean, sand, would be better than the coarser kinds, and recent tests made under the direction of the writer seem to show that extremely fine sand is not objectionable, if the concrete be well mixed, say by a machine mixer, revolving many times before discharging the contents.

There is the choice between the natural and the Portland cements for the third ingredient of the concrete. The former should never be used for work which is to be exposed to the action of the weather. Frost and sun are sure to destroy the bond of natural cement, and it should not be used (even in rich mortar) for pointing. Undoubtedly there is some economy in the use of natural cement mortar for the foundation work, where the same is not likely to be exposed, and is certainly better material than the earth

FIG. 12.—BRIDGE OVER CEDAR RIVER, JANESVILLE, IOWA. LYLE BRANCH, I. C. R. R. PIERS AND ABUTMENTS IN CONCRETE.

on which it rests, and to which it carries the load of the work above it. But the difference in cost between natural cement concrete and a Portland cement concrete of equal strength is little or nothing, and if there is any doubt, the decision should be in favor of the latter. There are such a vast number of American Portland cements, now being manufactured, that it is almost unnecessary to refer to the old idea that the best work should be done with "imported" cement. Within the last year comparative tests would indicate that our American cements are equal to any that are being made. Whether they will stand the test of time is yet uncertain. It is essential to specify that any cement should be furnished subject to testing and approval, as there are many cheap cements in the market, and all loopholes should be closed lest they get in the work. It is the essential characteristic of good cement that it should increase in strength as it grows older, and no test can be entirely satisfactory that does not show such increase. The twenty-four-hour neat test need not be very high, say above two hundred lbs. per sq. in. tensile strength, but the seven day test should show a decided increase, and the twenty-eight day test must continue to increase, or there is something wrong. It is, perhaps, a more satisfactory result to find that the tests on briquettes made with two parts of sand show a tensile strength nearly approaching that of the neat cement. All cement should be carefully protected from moisture, and none should be used that is lumpy or partly set.

2d. The method of mixing the concrete must be thorough and should be by machine, where this is possible. Many times this is impracticable, and hand-mixed concrete must be used. In either case, the proportions specified for the work should be measured with considerable care, and, unless the machine is provided with measuring facilities for delivering the proper amount of each ingredient to the mixer, some kind of hand mixing will be necessary. If the sand and cement are first combined and water is added

to make a mortar which is then turned over once or twice till well mixed, and if the stone be then added, first drenching it with water, and if the whole be then turned over twice before loading into the barrows or other means of conveying it to the work, the advantage is had that no chance exists that the mortar shall be washed off the crushed stone, since none will be needed after the stone is added, and the necessity for an extreme amount of labor for mixing in the stone will be avoided. It should be possible in this way, also, to get a concrete of equal consistency as to the water, a difficult thing to accomplish where the water is added to the whole mass. The above method is open to the objection that there is some danger that the cement may set during the subsequent processes of mixing and handling, but this should not be the case, if small batches are mixed. The latter should be the invariable rule, as no good work can be done when over a yard is mixed at one time.

3d. The concrete should be put into the work in a methodical and uniform manner. Placing concrete in the molds is often considered by the contractor as a legitimate portion of the mixing process, and he is apt to argue that the concrete will be well mixed by the time it is so placed. This should not be allowed. No act of placing should be necessary to complete the process of mixing. The usual way of handling concrete in wheelbarrows, if properly managed, will permit of carrying out the customary specification of making no layer to exceed six inches in thickness. It is all wrong to permit the laborers to pile up the concrete and then try to shovel it into a layer. This generally results in separating the large and small stone, or in leaving too thick a layer in the base of the heap. The ramming never corrects this, and some of the work is spongy, some too wet, and the

FIG. 13.—C. H. & W. R. R. SUBWAY UNDER I. C. R. R. AT RIVERDALE, ILL. ABUTMENTS IN CONCRETE.

whole result is bad. Thin layers should be insisted on, as thick ones cannot be compacted, and porous concrete is always poor masonry. Again, layers should be carried all the way across the work, or, if this is actually impossible, a square partition should be made in the mold, against which the end of the unfinished layer can be tamped; and if a great number of layers have to be left unfinished, a series of steps, or a square, vertical end should be made, depending upon the desirability of making a joint (for expansion, perhaps,) in the masonry at a given portion of the whole structure. No wedge shaped layers should be permitted either in the foundation or other portion of the work.

Neither should loose stone be left on the top of a layer. These act as so many picks under the heels of the laborers, grinding and tearing up the

FIG. 14.—C. H. & W. R. R. SUBWAY UNDER I. C. R. R., NEAR BROADVIEW. ABUTMENTS IN CONCRETE.

surface of the layer, and breaking the bond. One of the most glaring defects in concrete construction is the irregular wavy line, so often seen, and more or less clearly defined by different colors above and below, which is caused by stopping the work at the irregular line, and then resuming after a day or more, leaving a blemish which a little forethought, or a careful observance of reasonable rules would have prevented. If it were understood and invariably practiced that no work should be done to any but horizontal or vertical lines, there would be no such marks on the face of the work, and no occasion for either the inspector or the foreman to say that the work was unexpectedly stopped, or that nobody was in fault.

4th. The concrete must be thoroughly tamped. This feature of the work cannot be too much emphasized, and it is the thing which is generally

most slighted. If made of the right consistency all the porosities in the mass as it comes from the barrow can be eliminated, and a compact mass, in which all the interstices between the pieces of crushed stone are filled with the mortar can be made, and this is the essential feature of good concrete. Probably the strongest concrete would be made by having just enough water to fill the openings when the whole should be thoroughly compacted, but, owing to the probability that enough ramming cannot be had, it is on the safe side to have the concrete a little too wet. Some specifications provide that the mass shall quake under the ramming, others that it shall be on the point of quaking when in the barrow. The writer thinks the former the wiser specification, but would prefer that quaking be not too easily produced, and, but for the weakness of human nature above referred to, would rather specify that heavy ramming should flush the surface of the concrete, and not produce any quaking. As a corrollary to the above molds must be substantially built, so as to be unyielding.

5th. A facing of richer mortar should always be put against the mold for a skin on all exposed surfaces. Various ways have been tried to give this outside finish without making a special mortar for the purpose, but they generally fail at the most critical points, and a porous and pitted exterior is the result, one that never can be made to look well. Working the finer portions of concrete to the face with a special spade; throwing the concrete with a shovel against the mold, thus making the mortar stick thereto, and robbing the mixed concrete of some of the mortar for a skin composition, are some of the means practiced, but none of them is certain of the desired result, and it should be insisted that at least one inch of separately mixed mortar be placed against the mold, and that some means, as, for example, a movable partition, be used to confine and measure the right quantity of the mortar so that a hard, tough skin is formed and tamped with the layer, both setting simultaneously. Probably it should be further specified that this mortar be made with the same cement that is used for the body of the work. This would be on the safe side, though good work may be made by using natural cement for the body and Portland cement for the skin, only in that case the skin should have a much greater thickness than where the same cement is used throughout. No plastering of any coating upon the outside of concrete work which has set should ever be allowed. Such plaster is pretty sure to become loosened and peel off. If for any cause new work must be added to old, it should have a substantial thickness, and the old work should be well roughened, and thoroughly wet before the new material is added, and even with these precautions, the result will be doubtful. The top surfaces of all work should always be finished with a skin of mortar, of the same cement, and of the same general character as has been described for the face work. As specified for that work, this skin should be put on before the concrete work underneath has set. Where wing walls have to be made on a slope, the surfaces should be finished in short sections, in order to apply the skin coating on work which is not set, and the best way is, perhaps, to line off the top of such wings into separate stones, or blocks, the mold being finished to the proper slope as the wing is carried up.

6th. Above all, it is essential that the ingredient with which the famous artist mixed his colors should be liberally used in the construction of concrete. "Brains" are no less required in this than in painting, or in any other

work. The very ease with which this kind of masonry can be done, makes it the more needful that every step should be taken on a scientific basis. The thousand and one variations which can arise in carrying out a piece of work should be taken advantage of to secure a monolithic, homogeneous mass, lacking which, no concrete is worthy the name. At the same time provision should be made so that the natural forces always at work shall not destroy the structure. Monolithic work is desirable, but heat and cold will not respect it, and will destroy a wall that is not built to resist them. Joints are desirable, not only to provide for expansion, but to prevent destruction by unequal settlement. Work must, therefore, be built in sections that can expand and contract independently. These would vary in length under different conditions of temperature and exposure, probably between twenty-five and one hundred feet in length, the latter being used only in very heavy walls, abutments, etc., where the mass of earth on one side reduces the effect

FIG. 15.—ST. CHARLES AIR LINE DRAW OVER SOUTH BRANCH CHICAGO RIVER. CENTER PIER RAISED WITH CONCRETE.

of temperature. A concrete wall, built last fall, along the top of the levee at Cairo, Ill., to provide for extraordinary high waters, was made in one hundred feet sections, blind joints being made by constructing each section against a cross bulkhead, or against a piece of wall already set hard. In the winter each joint opened from a sixteenth to a thirty-second of an inch, enough to make it evident, that, without the joints, it would have been only a question of time before irregular cracks would have destroyed the integrity of the walls.

It cannot, therefore, be truly said that concrete is always easily constructed, nor is it always satisfactory; but its cheapness as compared with stone masonry, will make it available in many cases, and the field of its usefulness will continue to increase as the numbers of those who study and practice its construction grow larger, and as the proper methods of manufacture are better understood.

H. W. Parkhurst,
M. Am. Soc. C. E.

BRIDGE EVOLUTION AS RELATING TO SOUTHERN CALIFORNIA.*

[Continued from May Number.]

THE endeavor will be made by the description of some recent municipal bridges, with which the writer was connected as chief engineer for the designing and constructing company* to bring out some of the up-to-date methods of design.

The United States has reached a period in its existence where public or municipal improvements are being made of a more permanent character. The former practice of building bridges which were simply structures of utility, is giving way to a desire for something of an æsthetic nature as well. Where the money is available stone arches are being considered, and in many places constructed. The proposition to build a stone arch bridge over the Tennessee River at Knoxville several years ago provided for the construction of four stone arches of 240 feet each! (Fig. 16.) Such a structure built of Tennessee marble or else granite would have been possible, but on account of the certainty that the cost would be very great and likely exceed the estimates that had been made, it was decided to build a steel bridge, and competitive plans and bids were called for, with the result that the bridge designed by the writer for the company with which he was connected was adopted (Figs. 16 to 22.)

The design was for a cantilever structure 1,512 feet in length, which has five spans of 252 feet—two of which are fixed spans and three cantilever, with two shore arms of 126 feet each. To comply with the desire for an arch bridge, the bottom chords were arched, with a rise of 30 feet, and the entire section of the bottom chord made of built members, of plates and angles, 30 inches deep, solely for appearance. The arching of the bottom chord of the fixed span was against economy, and to some extent against stiffness, but to have made it straight would have spoiled entirely the effect. The depth of trusses at the center of the span was 20 feet and over the piers 50 feet. The two panels of each span next the pier were subdivided trussing, the four panels at the center of triangular trussing to avoid the use of counters, while the other panels were of the Pratt type.

The bridge carries a 30-foot paved roadway and two 6-foot paved sidewalks, with a combined live load capacity of 4,200 pounds per lineal foot, the pavement being of concrete steel construction, on steel joist, with wearing surface of cement on both roadway and sidewalks. The sidewalks are protected by a close lattice railing 4 feet in height, which joins a cement balustrade on the abutments, of proportions which were adopted from the base of a Tuscan column. The floor beams were made of riveted lattice construction, riveted to the intermediate posts of the trusses to assist in making the bridge stiff sidewise, while at each panel below these beams were diagonals of angles. Between the pier posts the diagonals are of four angles latticed the full width of the posts, thus forming with the horizontal

* Read before the Engineers' and Architects' Association of Southern California.
* The Youngstown Bridge Company.

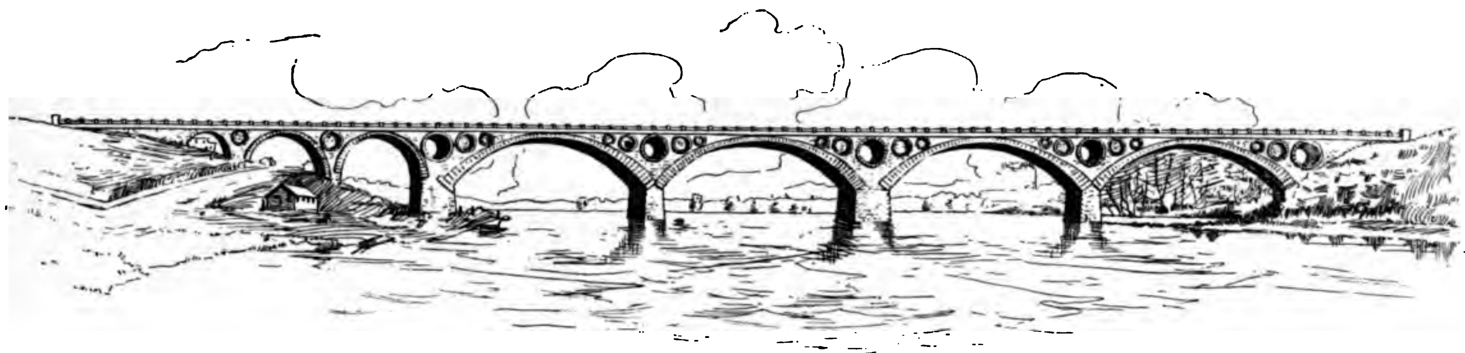


FIG. 16—KNOXVILLE STONE BRIDGE DESIGN.

FIG. 17—KNOXVILLE ARCHED CANTILEVER.

struts a very stiff tower. The pins at the top and bottom of these posts were 7⅞ inches in diameter, the bottom one engaging the built steel shoe, which was 4 feet 6 inches in height and weighed about 4 tons. The expansion rollers on two piers were of the segmental type, 12 inches in diameter, providing for a movement of 5½ inches, and resting upon built steel bolsters.

Where the bottom chords of the anchor spans were subjected to large tensile strains, owing to the difficulty of making a tension splice between adjacent sections, eyebars 10 inches in depth were employed, and to insure perfect action it was necessary to have but a very small variation in length in both the built members and the eyebars in the same panel. Two steel tapes specially standardized for the purpose were purchased, with an

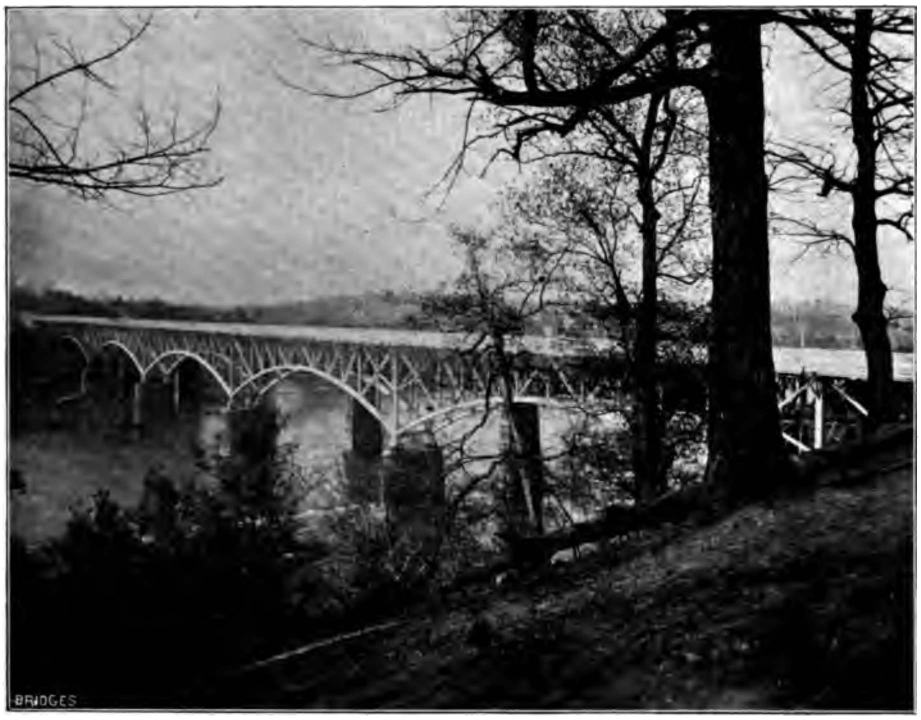


FIG. 18—KNOXVILLE ARCHED CANTILEVER.

extra foot graduated to 32nds of an inch, thus making it possible to measure the members and bars to 64ths.

The total height of the bridge was in the neighborhood of 110 feet, the piers being over 50 feet in height and built of iron limestone, with both ends of each pier lancet-shaped. The abutments were of Monolithic concrete construction, the proportions of the concrete being 1 of cement, 4 of sand and 7 of broken limestone, with a six-inch facing of 1-2-3 concrete. The structure with its five arched spans is very striking in appearance, and is believed to be a distinct advance over the usual broken outline which has been adopted for other cantilever bridges.

The Spring Common bridge at Youngstown, Ohio (Fig. 23), was designed to take the place of an old wrought iron arched truss. The span

FIG. 19—KNOXVILLE ERECTION.

was 174 feet, the roadway 40 feet and the two sidewalks 10 feet each. The entire paving was of concrete—steel construction on steel joist, with cement wearing surface. Where the truss members passed through the floor, castings with checkered flanges were used, fitting around the members, and having the cement finished up to the flange.

The sidewalks are protected by a close lattice rail of similar design to the Knoxville, with newel posts of special design, which were also of the proportions of a Tuscan column, except as to height of shaft. The bridge trusses were of the Warren type, with sub-verticals of four angles and a plate. Where the two stiff diagonals meet at the center of the top chord, a three-pin detail was used to avoid staggering the members. The floor beams were of necessity very shallow and were riveted between the posts, with the steel joists resting on shelves, between the beams. The top lateral system was of struts with web plates punched out in ornamental forms, and the diagonals of two angles laced vertically; the portals and three of the intermediate struts were deep, with web plates, and provided with curved brackets, which were finished against the struts and truss members by curved castings. It was the endeavor to have everything present a finished appearance, and the success attained may be judged from the view. Attention is here drawn to the necessity of making trusses for carrying pavements much deeper than is the usual practice, the proportion of one-seventh the span for ordinary trusses should be increased to nearly one-fifth.

The Market street bridge at Youngstown (Figs. 24 to 26) illustrates four other types of construction for municipal bridges, the plate girder span, viaduct construction, riveted lattice spans and the plate girder arch span hinged at the abutments. The structure is 1,610 feet in length, with plate girder approaches, in spans ranging from 30 feet to 90 feet in length. These girders are carried on towers which have headroom for driveways underneath, the wind stresses being provided for by portals with curved brackets, which produce bending stresses in the columns which were provided for in

the sections of the posts. The diagonals, instead of being light rods, are of two angles laced together, forming really stiff bracing. The span over the river which is 210 feet 6⅞ inches in length, is a plate girder arch of 60 feet rise, the girder being nearly eight feet in depth over all, and carrying the roadway by six columns on each of the two arch ribs, in addition to which there are two columns, resting directly upon the 10⅛ inch shoe pins, supporting lattice trusses 30 feet in length, on which the floor beams rest directly. The bracing of the arch ribs is of stiff construction entirely, angles latticed being the prevalent form.

The spans flanking this arch on either side are 165 feet 5⅜ inches riveted deck trusses of the Warren type, with an unusual form of sub-trussing which is triangular to be in harmony with the 30-foot trusses over the arch and to continue the horizontal effect of the girder approaches. These spans were made 30 feet in depth to give the effect of solidity on either side of the arch.

This bridge shows to what extent we in this country are adopting the European methods of bridge construction—making use of riveted methods in detail, but retaining the simple unambiguous forms of bracing.

The roadway on this bridge was 40 feet in width, while each of the two sidewalks was 7 feet in width with cement paving, but the roadway had an asphalt wearing surface 1½ inches thick. The live load capacity was 4,720 pounds per lineal foot. All of the bridges described were calculated to carry electric street cars and heavy road rollers.

The lessons to be learned from the evolution in bridge building as outlined in this paper are plain. Not only has steel become the material for use in permanent structures of moderate cost, but the types of trussing for use are well fixed upon. The Howe truss, the Pratt combination, as well as other forms in which wood is largely used for bridges in Southern California, have been entirely superseded by steel bridges in nearly all the country east of the Rocky Mountains. It is still possible to construct timber

FIG. 20—KNOXVILLE ERECTION.

bridges in the east at less expense than for all metal structures, and at Denver, where they are building steel bridges and have a much higher rate of freight on structural steel from the east than has this coast, timber bridges can be built at less cost than steel ones, but at best the timber ones are but temporary structures, and they have been supplanted by something more permanent. In the case of a bridge of three spans of 100 feet, with 20-foot roadway, the additional cost for using steel in Southern California would only be about 15 per cent on the total cost of the structure, piers and abutments included.

The rapid destruction of wooden bridges by the eastern climate was one of the causes for substituting steel, which does not exist to so great an extent here in this dry atmosphere, but the shrinkage of the timbers away from the metal connections, leaves such a structure a loose-jointed affair, it being possible to make but a poor connection between the timber and iron

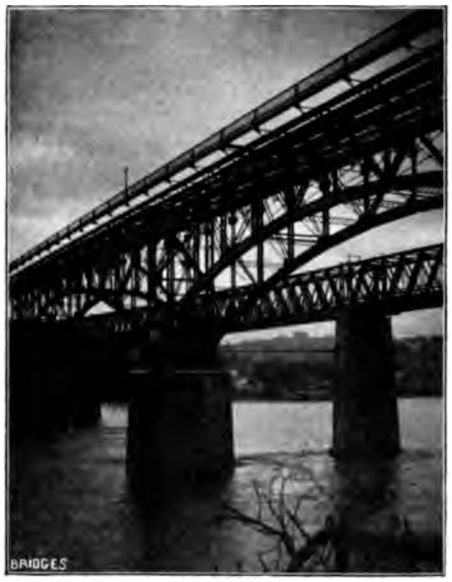


FIG. 21—KNOXVILLE DURING ERECTION.

or steel at best. The dryness which prolongs the life of timber is no less beneficial in the case of steel by causing little oxidation; on which account steel bridges in the east should be newly painted in from three to five years to preserve them, but here, if allowed to go unpainted, as is most often the case with municipal structures, but little damage results.

The greater demands upon the forests of the north coast country must before long cause a greater cost of timber to be a factor in deciding what class of structure to use, but we will assume that the engineer having the decision as to what material to employ will decide upon more permanent steel structures, and outline in a general way the best types to erect in various locations.

The first step toward a permanent bridge is to construct permanent foundations. Those of stone are, of course, the only kind to construct

where good stone can be had at reasonable cost, but where it is not plenty, tubular steel shells filled with concrete are often used. This form of pier is so common here as to require no extended description. The materials for concrete are so plenty and of such fine character, while Portland cement can be obtained at so reasonable a cost that the use of monolithic concrete piers should be seriously considered. The practical absence of frost makes it possible to use such proportions for concrete that the cost will be but little more than for tubular piers of the best construction. The proportions for the heart of a pier may be one of cement, five of sand and eight of stone, with a facing of 1-2-3 concrete, and with care in doing the work excellent results may be had. Proportions of 1-3-6 for the heart concrete are, of course, much to be preferred, provided it is possible to increase the expenditure to that extent. The footing courses may be on piles and a grillage beneath scour line, but if rock can be found at less than 20 feet below low water, coffer-dams should be used and the pier built upon rock. For bridges the superstructures for which are of a permanent type and of considerable

FIG. 22—KNOXVILLE BALUSTRADE.

cost, it would seem wise to found the piers on bed rock, even at a depth of 40 feet by using the pneumatic, or compressed air, process which is now in very common use, and can be employed at a cost of from $12 to $15 per cubic yard.

The superstructures should be designed with careful consideration of the economical span length, which is dependent upon the capacity of the trusses, the height above the stream or the cost of piers and abutments. As an example, may be cited the case of a large city erecting a span of 125 feet deck plate girders, with but 7 feet from the bottom of the girders to the bed of the stream, whereas the use of two spans of about 65 feet with a middle pier would have been much cheaper, as it would have been possible to build the pier at a very low cost. This has recently been done in building another bridge over the same stream. Had it been impossible for any reason to construct the center pier, then the span should have been an open web or riveted lattice structure, instead of the plate girders. The streams of Southern California are many of them broad and with low banks, indicating economy in the use of short spans—probably in many places less than 100 feet.

Where the crossing is exceptionally low, half through plate or lattice girders could be employed.

For bridges over the streams in the mountains or foot hills, where the height above the stream is great, longer spans will be necessary, often longer than economical, to avoid placing piers in a mountain torrent where they would be destroyed. The tendency is to make riveted spans for many bridges up to 200 feet in span, but for shipment overland it is wise to adhere to pin connections, making the end panels of the bottom chord and the long suspension members of stiff construction. The writer has gone so far in the interest of stiffness as to make all members in some 100 feet pin connected trusses of shapes or stiff construction, and in some 250 feet spans the end bottom chords, the hip verticals and the first main diagonals were four angle or stiff members.

Where a bridge is so situated that it will be in full view, especially in a

FIG. 23—SPRING COMMON BRIDGE.

city, some attention should be paid to making it artistic in appearance. The use of arches of various forms is very much in vogue, and they are readily constructed in steel at a slight increase in expense over the more prosaic kinds of bridges. The least that can be done is to use care in making a finished structure, designing each detail so that it is not only inoffensive but as pleasing as possible.

The use of the Melan arch for a number of prominent bridges and a host of smaller ones, warrants a brief mention of it. In appearance it is a concrete arch bridge, where the depth of the arch is very small at the key. In construction the arch proper is formed of concrete, having imbedded therein ribs of steel, that form a compound construction, in which the tensile stresses are provided for by the steel ribs and the compressive stresses by the concrete, thus making a very much lighter and cheaper arch than would be possible by the use of concrete alone. The concrete is susceptible of artistic treatment with small trouble, thus making such a bridge very

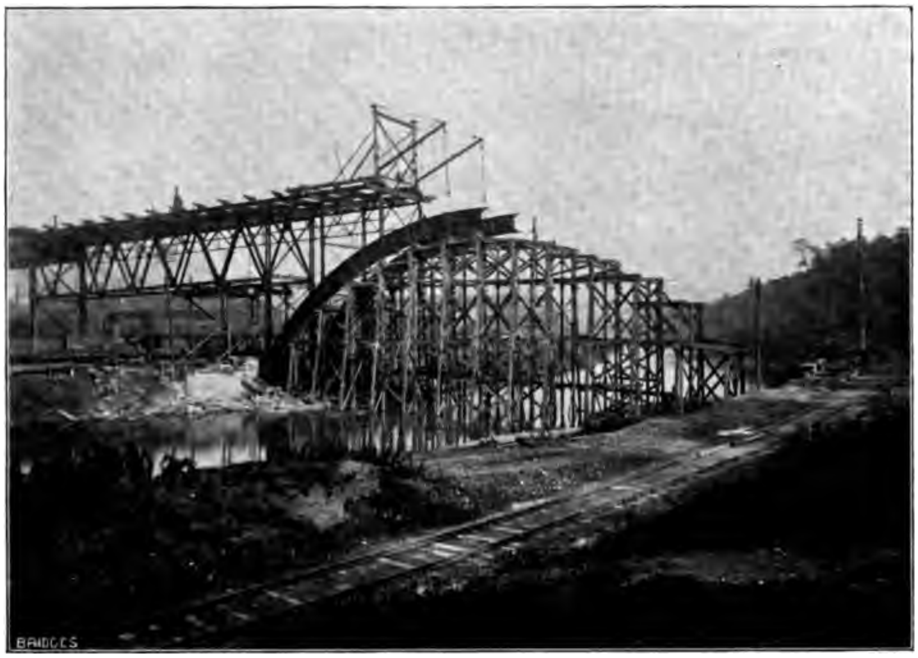


FIG. 24—MARKET STREET PLATE GIRDER ARCH.

FIG. 25—MARKET STREET PLATE GIRDER ARCH.

suitable for locations where something especially attractive is desired. In many locations they can be built at about the same cost as a steel bridge and abutments. The Melan arch in Eden Park, Cincinnati, and the bridge at Topeka, Kan., with five spans, are handsome examples.

With permanent bridges, permanent roadways should be used for city traffic. The steel joist may be used to support buckle plate flooring, on which concrete is placed as a foundation for brick, cement, or asphalt paving. Or some form of galvanized sheet metal floor may be used on which to lay the concrete. Some bridges have recently been built with concrete arches built between the joist, with a thickness and strength sufficient to carry the pavement and the loads. To avoid the necessity for centering on which to construct the concrete arches, corrugated iron arches may first be

FIG. 26—MARKET STREET TOWER.

laid upon the lower flanges of the beams, which will serve as centering, and add to the strength of the floor.

Except in some few localities, where stone is to be had of fine quality and at low cost from quarries near to bridge sites, the building of large stone arch bridges has not become at all common, even in the more thickly settled and richer portions of the United States east of the Mississippi, nor does it seem likely that in the near future the building of them will be much more frequent, except as monumental or memorial structures. For short spans, up to 50 feet perhaps, they are quite frequently built where permanent bridges are desired. In the more thickly settled portions of Southern California not expense alone is against their being built, but the character of the streams make them undesirable. Where the streams are narrower and the banks higher, as in the mountains, there is not travel sufficient to be expected to call for such bridges.

The part which the suspension bridge has played in the evolution of bridges has not been discussed, because of the fact that a suspension bridge of first class design costs as much or more than some other type of bridge, except for very long spans, while one of poor or even medium design is such an unsatisfactory, if not dangerous, form of bridge that it should not be built. The designer of the Victor wire bridge which collapsed about eight years ago, had evidently convinced officials to the contrary when securing the contract, but the failure showed that an error had been made which need never be repeated in this glorious sunny country.

It is hoped that this association will use its influence for the construction of artistic and permanent engineering works, even though the expense may *seem* injustifiable, in the firm belief that the near and exceedingly prosperous future, to which all signs point, will be the vindication.

C. E. Fowler,
M. Am. Soc. C. E.

LAW POINTS ON THE CO-RELATION OF THE CONTRACT TO THE SPECIFICATION.

INTRODUCTION.—The use of the terms "contract" and "specifications" as designating two separate and distinct instruments or documents is a misnomer. The "contract" usually does and should embody, not only the specifications, but also the plans, the proposal, and the advertisement for proposals. In legal contemplation, these taken together are the contract, and they should be connected either physically or by clear reference so as to identify one another as the parts of one contract. It is the engineering or architectural profession that distinguishes the terms *contract* and *specifications*. This use comes from the practical operation of building, and the constant reference to the specifications to ascertain the character, quality, and finish of materials and work which are defined in the specifications; while the rights, privileges, and obligations of the parties are set out in the contract. To the former, the engineer and contractor have constantly to refer and to the latter infrequently. To the legal profession, the general provisions, the specifications, the plans, the bid, and the schedule of prices, comprise the contract. If there be conflict between the parts, it is simply an ambiguity which is to be cleared up by the application of general rules for the interpretation of instruments; the aim and object of which is to ascertain the *intention* of the parties. If the *intention* be known, it will prevail.

If there be no ambiguity or uncertainty, no evidence of the intention of the parties will be admitted by the court, but the court will confine its investigation to the four corners of the contract; and if there be uncertainty no evidence will be admitted of understandings, agreements, conversations or terms arrived at previous to, or at the time of, making the contract. The written contract will be presumed to contain all the terms of the contract, and nothing can be added to or taken away by parol proof or explanations.

While the technical use of the word "contract" comprises the several parts, including the specifications, yet for the purpose of discussion and to conform to the use of the words as employed in the industrial professions, the writer will use the terms according to their popular meaning.

In the beginning it may be stated that, only so far as the particular physical conditions existing in bridge building may effect a case, the relation of bridge specifications to a contract for a bridge or framed structure, is not different from that of any other class of work, and what may be said of the relation of contracts and specifications for bridges and framed structures will apply to almost any other class of engineering or architectural work.

The Contract.—The contract should create and impose the obligations of the parties, one to the other. It should define the rights, duties and relations of the parties and in such a manner and in such terms as to make them clear, valid and binding. Every valid contract must possess four essential elements, namely: (1) two parties, with capacity to contract; (2)

a lawful consideration, a something in exchange for its legal equivalent; (3) a lawful subject matter; (4) a mutual understanding, or meeting of the minds of the parties. No agreement so called is a binding contract unless it embodies each and all of these elements. Without them the courts decline to enforce the agreement and the parties are free to fulfill their obligations or not, as they please. The contract should describe the parties, the consideration, the mutual understanding and the subject matter, and such conditions and stipulations in regard to the parties, the time of commencement and completion of the work, the payment therefor and the general relation of the parties, their agents and employés.

The "contract" is frequently embodied in a general form, adapted to different kinds of work upon the line of the railroad or canal, or for general improvements of the city. When such a contract form is required to do service for several kinds of work, it should contain only those conditions and provisions that have a general application to all work. Such a practice saves a great amount of expense required for printing, and relieves officers and attorneys from much labor. It is good practice. The contract becomes then the legitimate work of the attorney, and the preparation of the specifications and plans falls to the engineer or architect, both to be carefully examined and discussed by the attorney and engineer jointly. When this is done by professional men, experienced in construction work, much litigation and many misunderstandings will be avoided.

The contract should provide for finished or complete structures. It should be made entire and the specifications, plans and contract made to agree, and it is submitted that the saving clause should be inserted into the contract which declares that such is the intention of the parties. A contract which provides for a finished structure protects the owner in case the work is destroyed or is defective. It imposes upon the contractor the liability for the sufficiency of the plans and specifications. In case of payments having been made and the structure destroyed, it enables the owner to recover back such payments. Invariably the owner or company want a finished structure, and the engineer is usually the safest and best judge of what is a complete structure. What the county, city or railroad wants is a serviceable bridge, not a certain quantity or a certain number of tons of steel, nor a certain number of lineal feet of structure, nor a certain number of cubic feet of masonry.

The Specifications.—The specifications should embody the plans, and they together should give a full and complete description of the materials and work to be furnished and of the structure to be erected. Together they should contain all the dimensions, instructions and directions necessary to secure the *result* sought to be accomplished. The description of materials should be made by such tests and comparisons, that if two contractors have work upon adjoining sections, with but an imaginary plane between them, the engineers of the two sections respectively would and must arrive at the same result, whether it be one of measurements as the area of the cross section dividing the two jobs, or merely one of classification. The specifications and plans should definitely describe the site of the structure, and usually it should define the process of manufacture of materials, and the finished materials of construction, not only positively as to good properties that they shall possess, but negatively, naming the defects that they shall

not contain. They should provide for inspection and tests at the mills and shops, and for inspection during erection, and every type of work should be described in sufficient detail to enable the builder to complete the structure without further directions from the engineer or superintendent.

The several parts of a contract must be connected. If they be not physically joined together, then they constitute different documents, unless there be a clear reference in one to the other. Without such reference one cannot be read into the other so as to define or modify the obligations assumed by the parties. A contract may consist of two or more writings, but they must be connected either physically or by clear reference in one to the other. Without it parol evidence cannot be introduced to identify the several parts of a contract. A simple reference and description which identifies plans, drawings or specifications will make the latter a part of the contract; and, when such reference has been made, parol evidence may be admitted to identify the writing or drawing referred to.

The specifications may consist of a letter written and signed, or of a mere sketch, with description of materials and methods to be employed inscribed thereon. Plans exhibited to contractor when contract is entered into should be referred to in the contract, so that the two writings may be connected together. This is also true in an act of the legislature. If the act itself does not refer to the plans, sections, etc., they cannot be thereafter used in construing the act. The plans and specifications exhibited to a contractor may be introduced in evidence to show how work was required to be done under a contract.

It frequently happens that specifications or plans are referred to as signed or attached when they have not been signed or attached. In such case, parol evidence may be introduced to show what specifications were intended to hold or were actually agreed upon, and some cases have held that they are in legal effect incorporated into a contract. However, it must be shown *what* plans and specifications were referred to, and to do this parol evidence may be introduced. If the plans and specifications can be identified they will hold, even though they were not signed or attached, as stated in the contract.

A contractor may undertake to build in accordance with such plans and specifications as may be prepared or furnished by the engineer or architect, and he will be held to his agreement, notwithstanding the plans and specifications furnished differ materially from those exhibited to the contractor when he made his bid and also materially change the value of the work. Ordinances and regulations referred to in a contract are a part of the contract, and will hold, not only as to the manner in which work shall be done, but also as to how it shall be paid for.

Under a contract to erect a structure in conformity with specifications, in a good, workmanlike and substantial manner, to the satisfaction and under the direction of the architect, and that the foundation should be not less than ten feet in depth, the contractor was not required to excavate to a greater depth without additional compensation; even when the contract provides that extra work involved by any change in plan shall be paid for at contract rate for work of its class, at a certain price per lineal foot. The contractor may recover the actual increase in the cost if the extra work required is of much more difficult character than that required

by the original plan. When a contractor has agreed to build some bridges according to certain plans at a certain rate of compensation, and to make additions at the same rate, it was held that the contractor was not required to make additions and to do a class of work which was more costly than that contemplated by the agreement.

If the limits of work are defined or are shown upon the plans by boundary or dividing lines, whatever is required outside or beyond such limit have usually been held extra work. An undertaking to furnish all materials and labor for plumbing will not preclude a recovery for extra work caused by changes made in the specifications and plans, and changes made in the original plans when working drawings are prepared, and the work has been done under such working plans, the contractor may recover for changes directed by the owner which makes work done conform to the original plan. If bids have been made and accepted on the original plans and specifications, and the working plans afterward furnished vary from the original plans, involving much additional work, and the contractors have refused to continue the work at the contract price, and the owner has employed others to do the work at an increased compensation, the contractor may recover for the work he has done, if the variance between the original and working plans was material. If, however, the contractor had performed the work without protest, he very likely would have been held to have done the work under his contract.

Conflict of the specifications and plans with the express provisions of the contract proper.—When the provisions of the contract, so called, do not agree with the specifications, they are said to be in conflict, and it becomes a question for the judge to determine what was the intention of the parties as set forth in the instrument, taken as a whole. The duty of the court is to determine the *intention* of the parties, and, in order to determine that intention, the entire contract will be considered, not only in the construction of any part, but in the interpretation of the whole. The intention of the parties must be legal, or it cannot control. If not incompatible with the rules and maxims of the law, the mutual intention will prevail, and this is called the polar star in expounding all instruments. The court will, so far as possible, put itself in the position of the parties at the time the contract is executed, and will consider the condition and circumstances under which they assumed the contract obligations. The conduct of the parties and the practical interpretation which they themselves have given to the terms of the contract will be given its proper influence if the intention be not clear as expressed, thus: when the contract and specifications do not agree with the working plans furnished, and the work has been done under the direction of the engineer according to a plan, model or sample furnished, the practical construction which the parties have adopted will prevail over the literal meaning of the contract and specifications.

Other things being equal, the contract is usually held to prevail over the specifications. The former is a more ceremonious undertaking, and usually defines the obligations of the parties. It is the culminating act by which the obligation of the parties is assumed, and is rarely subject to alteration. On the other hand, the specifications and plans are descriptive of the work and the manner in which it is to be performed, and are almost always sub-

ject to change or modification, as conditions and circumstances attending the performance of the work may arise.

When, therefore, the contract required cornices in twenty-five rooms, and the specifications required cornices in the halls and all the rooms, and the owner selected twenty-five rooms to be corniced, it was held that the contract should govern, and that the contractor was not required to run cornices in the halls and storerooms. In another case where the contract provided a mode of determining extras and the specifications provided a different and inconsistent mode of determining extras, the contract was held to prevail. A guarantee expressed in a contract as to the capacity or service of works will not be controlled by specifications containing statements as to distances, dimensions, etc.

It should always be borne in mind that the duty of the court is to determine the *intention* of the parties, and the contract prevails over the specifications only because and for the reason that the circumstances attending cases in general lead the court to give greater weight to the contract as expressing the intention of the parties. If there be any attendant circumstances that show, or even indicates with sufficient certainty that the parties intended that the specifications or the plans should control, the court will be bound to so interpret the intention of the parties and any one of the parts of the contract, namely: either the specifications, the plans, the proposal, or the contract may prevail.

Conflict Between Plans and Specifications.—From what has just been said of the matter of intention of the parties, but one conclusion could be arrived at with regard to the plans and specifications. With regard to plans, it may be said that they are cumbersome and not easily handled or carried about; to make alterations in them requires drafting instruments and scales, while the specifications may be changed quickly by a pencil or a writing pen, which are always at hand. It is therefore suggested that the specifications would probably be controlled ordinarily by the plans, so far as representing the original intention of the parties, but as any part of the contract is subject to modification and change by the parties, alteration in the specifications might control so far as the execution of the work was concerned, whatever might have been the original intention of the parties. Plans are prepared and submitted for the contractor to make his proposals upon. At the time of entering into the contract they are frequently left in the drawing room, and when it comes to the final determination of the terms, alterations are made in the written instruments at hand, namely: the contract and specifications; therefore, the contract and specifications should be and usually are held to control the plans and proposals, and the decisions of the courts are generally in sympathy with that view; therefore, when the specifications fix the size and character of columns for a structure, it was held that the contractor could not show that columns of a different size were more in accord with the plans.

In cases of disagreement between the parts of a contract the court will adopt that interpretation that will conform to both instruments, if it can discover such a way out of the difficulty. The court will, if possible, find such a meaning as shall be consistent with both papers. Therefore, where the specifications required all walls to be vaulted, and the plans show them to be sixteen inches in width, without vaulting or spaces, it was held that

the walls were to be sixteen inches, including the vaulting, and that evidence could not be admitted to explain the contract. When the specifications required walls to be plastered with K. & Co.'s cement, under the direction of the superintendent of K. & Co., and the specifications required that cement and sand should be mixed in equal parts, it was held that effect should be given to each requirement by holding that the superintendent's supervision applied to the laying of the cement plaster on the walls, and that the contractor could not use a less portion of cement in the mixture, even though the superintendent did consent to it.

Another circumstance to be considered in the interpretation of clauses which are in conflict one with the other is that the courts usually construe stipulations most strongly against the parties who used or prepared them. This rule has generally been applied, except where the government or public are the parties, in which case it is usually held that the meaning will be adopted which is most favorable to the government or public, holding that the interest of the public should be protected, because there is nobody who has the interest in the public's welfare that they have in their own.

Written and Printed Matter.—If in the contract or in the specifications the written portion of the contract is repugnant to the printed, it is a general rule of construction that the printed must yield to the written, as the latter is presumed to be deliberately expressed in the written portion of the contract.

To have any part of the contract control another part, it must be inconsistent or opposed to it. If the two parts can be reconciled the court is bound to do so; therefore, when the printed part provides that payment shall be made on the architect's certificates, and the written part provides that the payments shall be made at fixed stages in the progress of the work and at different times after its completion, there is no inconsistency between them, and neither part will be rendered inoperative.

A special written addition to the printed form is entitled to special weight, as it is presumed to have been separately and particularly considered by the parties, and to express their exact agreement on the subject.

Punctuation.—In construing contracts or legal documents punctuation has very little weight. The want of a punctuation mark will not be allowed to vitiate the contract or destroy its meaning, any more than bad grammar or bad spelling.

Work According to Specifications or as a First-Class Job.—When work is to be performed in a good, thoroughly workmanlike manner, and at the same time according to specifications and plans, the question arises as to whether the contractor is excused from making a first-class, workmanlike job if he has completed it according to the specifications and plans. An undertaking to construct a piece of work is an undertaking to do it well and in a workmanlike manner, whether this is expressly stipulated or not, but if the owner specified the materials, workmanship or the manner in which the structure is to be erected; and if, after completion, it proves to be defective, and does not fulfill the purpose for which it was intended, then the loss falls upon the owner, who has specified the materials, workmanship and manner in which the job should be finished. This was so held when the owner required the contractor to follow his directions in making an experimental

article from a pattern furnished, and the owner was required to pay, even though it was not fit for the uses contemplated.

Anybody who undertakes to erect a structure impliedly warrants that he is reasonably skillful in his trade or calling, and that the materials he uses should be suitable for the purpose for which they are used. A builder has been held liable for a defective chimney which would not carry off the smoke for which it was designed. The fact that the price to be paid is grossly inadequate does not excuse the contractor from fulfilling his undertaking to do a thoroughly workmanlike job. When the contractor agrees to execute a job in a plain and workmanlike manner, or in a manner to be determined by the engineer, he is bound to show that he has executed the work in a plain and workmanlike manner. This case would seem to show that the provisions to do the work in a plain and substantial and workmanlike manner was an additional safeguard to insure the satisfactory completion of the work. The words "plain," "substantial" and "workmanlike" do not imply an undertaking to do a perfect job, but that it should be a question of fact for the jury to determine and not for the court. It should be perfectly done, for the character of job contemplated. The expression cannot be overcome by showing a custom or usage which allows the use of inferior materials or unskillful work.

Directly connected with the subject of substantial performance, therefore, is the subject of the liability of the contractor for work, liability for the failure of the structure after completion, and caused by insufficient plans and specifications. Work done strictly according to plans and specifications furnished and adopted by the owner is done and completed at the risk of the owner, unless the contractor has either expressly or impliedly undertaken to guarantee the sufficiency and stability of the work. In Wisconsin it is held that when the State furnished the plans and specifications, and contracted that the work should be done according to said plans and specifications, and under the direction and to the entire satisfaction of the architect, that the State warranted the plans to be sufficient and suitable, and that when the contractor, in good faith, erected a large portion of the structure, and the materials and work had been accepted, he was not liable for the collapse of the structure if it failed in consequence of defective and insufficient plans. The same was held in the case of a machine that would not work when completed; in a case where a building settled and cracked because the footing stones were too small, the same having been specified by the architect; and a case where an arch fell because it would not sustain the load imposed upon it.

The contractor must have completed his work in a workmanlike manner. He must furnish good materials and must do his work in a thorough and substantial manner, and must also prove that the failure of the structure was due to the inherent defects of the plans and specifications.

The court sometimes distinguishes those cases in which the contractor is merely to build according to plans and specifications from those in which he is to completely finish and deliver up a structure ready for use. If the contractor undertakes to deliver up a structure complete, the courts frequently hold that such an undertaking is a guarantee that the plans and specifications are sufficient, and that by undertaking to complete and deliver up a finished structure the contractor adopted and approved of the plans

and specifications. This was held where a building was built according to various detailed plans and specifications, and, owing to the latent condition of the soil, the foundation settled. The court held that the contractor, having agreed to completely finish the building, fit for use and occupation, that he was bound by that covenant. So, too, where a contractor was to construct a well for a certain sum, according to specifications which called for a curb of a certain shape and size, to be made of timber and planking of a prescribed size and quantity, it was held that the contractor could not recover for the work and materials lost by the caving in of the well before completion, notwithstanding it was due to the weakness of the curb specified. If this well had been completed and accepted, the decision might have been different. If the contractor guarantees that the structure will answer its purposes, or that the machine will work, he will not be relieved from such guarantee because the plans or specifications are defective. The contractor's liability ceases when the work is finished and accepted.

An undertaking to erect a structure according to certain plans and specifications implies an understanding of them on the part of the contractor, and the law will not permit him to escape liability on the ground that he exercised ordinary care and skill to understand and carry them out. If the contractor departs from the working plans, which are part of the contract, they become guarantors of the strength and safety of the structure, but if the material deviations from the plans are made with consent of the owner, the contractor is not responsible for the destruction of work or from inherent weakness due to the mode of construction or from the violence of storms.

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BRIDGES OVER THE RHINE AT DUSSELDORF.

HAND in hand with the steady growth of trade and traffic on large navigable streams, goes the endeavor in Germany to free such streams from the most serious obstacle to navigation, namely, floating bridges, and to replace them by fixed bridges. The busiest of busy rivers is the Rhine, with its fleet of 900 steamers and 8,000 sailing vessels and barges on the stream itself, and an enormous amount of traffic from bank to bank. The latter in particular has increased in a noteworthy manner, since the Rhine has been not only Germany's border line, but her river.

It was in the year 1896 that the first arch bridge was built, and that was at Striegan, in Silesia. From that time until the middle of the present century, the only material available for such constructions was cast iron. This gave place to wrought iron, which, in turn, has been superseded by so-called fused iron, a grade of soft steel. In addition soft steel is a far less costly material than welded iron, and this circumstance has given a considerable impetus to the building of bridges.

Although Germany cannot claim to be on a level with America and England in the matter of bridge building, German bridge builders take the first place on the continent of Europe, and many of the bridges in foreign countries have been designed and built by German constructors.

The first big railroad bridge built in Germany was that erected in the '40's over the Rhine, between Kehl and Strassburg. It was supported by four stream and two land piers, and was a lattice work of pleasing and graceful form. The second bridge, built about 100 m. higher up the river than the one mentioned, for the street railroad, was also a box-like structure. It was finished in 1898, but cannot compare with the older one in beauty.

The Cologne lattice bridge, built between 1852 and 1859, 448 m. long without the platform, with three stream and two land piers, cost twelve million marks and meets all requirements of traffic, but it could not possibly be called beautiful.

Father Rhine was fortunately spared the horrors of more lattice bridges, as arch bridges became the order of the day. Such were Ludwigshafen, Mayence, Coblenz, Hamm bei Düsseldorf, and Wesel. All the bridges named were, without exception, built simply with regard to utility; the engineer and economy only were consulted; for the architect and the sculptor there was no money to spare.

That it is otherwise to-day is proved by the bridge for the street railroad at Mayence, the two bridges (one railroad, the other highway) at present in course of construction at Worms, the highway bridge at Bonn, and that at Düsseldorf, which was opened to traffic on November 12, 1898.

It is no easy task for the architect to find a balance for the arches, the spans of which are steadily growing greater. So far the proportions of the arch of the medieval gateway have been preserved in the bridge arches supported by the piers, and the overloading of the construction with too many architectural adornments has been pretty well avoided. But the limit in

THE NEW BRIDGE AT DUSSELDORF.

this direction would appear to have been reached in the bridge just completed at Düsseldorf.

Whereas, before 1890, a span of about 100 m. was the limit, 200 m. will apparently soon be reached. We may mention, as examples of the tendency of expansion, the following bridges: North Sea and Baltic Sea Canal, Levensan, 163.4 m.; Grünthal, 156.5 m.; the Sohngen-Remscheid railroad bridge, Müngsten, 170 m. at 107 m. above the water; the Rhine highway bridge at Düsseldorf, two arches of 181.25 m., and the bridge at Bonn with a middle arch of 187 m., so that, at the present moment, the last named is one of the greatest of existing arch bridges.

With which prefatory remarks we will turn our attention to a study of the new Düsseldorf bridge. Until 1818 communication between the opposite banks of the Rhine was by means of ferries; from 1818 to 1839 by a flying bridge; and from 1839 until November 12, 1898, by a floating bridge. The cost of construction of the last was 93,000 marks ($23,250), and the average yearly revenue for some time had been 80,000 marks ($20,-000). In 1849 the agitation began, to supplant the existing floating bridge by a permanent one, but at least half a dozen projects came to naught before four Commerzienrakhe, with Heinrich Lueg-Düsseldorf at their head, took the matter in hand, and put it through with a speed which, even in these days of quick action, is surprising, and particularly so when one takes into account the number of officials whose judgment had to be consulted, and whose scruples had to be satisfied.

From the revenue of the bridge neither the interest on the outlay nor the cost of building could be paid. Therefore there was linked with the project of building a bridge that of the construction of an electric railroad from Düsseldorf to Crefeld, which towns had communication by railroad only via Neuss, which communication was very poor.

An embankment of about 375 ha., on the left bank of the river, near the end of the bridge, was utilized both for the bridge and the railroad.

In this neighborhood there will grow up a new suburb of Düsseldorf, which will be a pleasure resort for the inhabitants of that city, and which will take the place of those which are now falling into disfavor. It will have the very great advantage of being in direct communication, by means of the electrical railroad, with the neighboring seats of industry, as well as with the depot of the State R. R. at Heerdt.

After, according to the Ministerial decree of February 26, 1896, all details had been arranged, boring operations were commenced in April of that year. It was found that the piers would have to be sunk as follows: The two land piers to 3 m.; the left main pier to 3.5 m.; the mid-stream pier to 13 m.; and the right side main pier to 12 m., under zero on D. P. The two last-named are built on iron caissons, while the others rest on a foundation of beton, which consists of one part of Portland cement, three parts of sand and six parts of Rhine gravel.

Trass was not used because in the cold season this material sets very slowly when at all, and in the case of the two piers which were sunk by pneumatic pressure the quick hardening of the beton was necessary. The lining under water followed with 0.5 m. rods of basalt. From that upward to the abutments, which are at the height of high water, the lining was of masonry of basalt lava, and the upper parts on the piers of Weiber tuff.

The square stones of the bridge head were strengthened by rough wrought bosses.

To assist in carrying over the heavy pressure from the iron arches the slips between the two opposite supports within the pillars are composed partly of granite and partly of Palatinate sandstone. The iron construction shows,

BRACED ARCH, WITH SUSPENDED ROADWAY, AT DUSSELDORF.

in the middle, two magnificent arches of a width of 181.25 m. each. The upper chords are seen without an interruption, while the bottom chords are beneath the roadway near the ends of the spans. At Düsseldorf low water is reckoned at +2.70 m., and the highest navigable water at +7.50 m. The roadway is 11.5 m. above the latter, that is to say +19 m. above zero; the under edge of the bottom chord at +37 m., and the upper edge of the upper chord at +42 m. above zero D. P.

The connection between the right bank and the main span is by means of

an adjoining arch of 60 m. span, over which passes the road leading from the port of Düsseldorf; while on the left bank of the river there are three arches of 62, 51 and 50 m. in span, respectively, and these are deck spans. All the arches are double jointed, of soft steel. The total length of the bridge between the end abutments is 638 m.; the width of the bridge between the balustrades 14.2 m., 8.2 m. of which are occupied by the double track of the electrical railroad (which is of the normal gauge as used on the State Railroad), and a road for general traffic; while the promenades on both sides are 3 m. wide.

In both main arches the footway is crossed by the tiebands, through the bottom chord, and the verticals and diagonals of the first panel, nevertheless the distance between the members is so great that no noticeable obstruction to the traffic is caused.

The main cross girders, which are made riveted section, are, in the first panel, riveted to the verticals, but in the others to the girders.

The middle portion of roadway is paved with wood bricks, the promenades are covered with asphalt on a bed of beton, and the two approaches on either side, which have an incline of 1 in 40, are paved with granite over a beton foundation, with somewhat large cracks between the blocks so that there will be the necessary hold for the shoes of the draft horses.

For the upper iron work 4,700 tons of soft steel, 190 tons of cast iron, and 100 tons of cast steel were used—in round figures 5,000 tons.

The technical plan of the construction was the work of Prof. Krohn, of Skerkrade, while the piers were built after the designs of Prof. Schill, of Düsseldorf. On the two piers at the opposite extremities of the bridge rise heavy portals in the Renaissance style, which, in the upper stories contain rooms for offices and dwellings for the bridge attendants.

On the upstream side of the head of the middle pier, looking toward Düsseldorf, is a basement on which is carved in stone the arms of the city —a powerful sitting lion, holding an anchor and coat of arms; while on the downstream side of the pier head there is fixed a massive flag pole.

The general appearance of the bridge, although the two gigantic arches taken by themselves are very fine, is not altogether satisfactory, as the main arches are not situated in the middle. The one land arch on the right against the three on the left bank, gives a much more inharmonious impression than could be desired from an artistic standpoint. But it must in justice be remembered that local conditions had to be taken into consideration, for instance, the filling up of the old harbor of refuge on the right bank, the leveling of the foreland to middle water height, and the carrying back of the left bank; the mass of soil of the operations mentioned amounting to about one million cubic meters.

The excavation and masonry work was done by the firm of Ph. Holzmann & Co., Frankfurt, A. M., under the direction of the Gute Hoffnungshütte of Oberhausen, as to them was let the contract for the upper part of the bridge and the finishing of the whole.

In June, 1896, the construction was commenced, and on November 12, 1898, the bridge was handed over ready for traffic.

The cost of building the bridge, not including the platforms, was, in round figures, as follows:

	Marks.	Dollars.
Piers to the roadway, including all the stonework	1,430,000	286,000
Buildings on the piers, including the lion	150,000	30,000
Iron upper works, including balustrades	1,840,000	368,000
Roadway and promenade	110,000	22,000
Hauling, etc.	270,000	54,000
Total	3,800,000	760,000

Reckoning the acquiring of the land, dumping, etc., for the platforms, building percentages, etc., the total amounted to about 6,000,000 marks ($1,200,000), which certainly cannot be considered unreasonable for such a great undertaking completed in so short a time.

Translated for BRIDGES from the German by L. DEV. MATTHEWMAN

THE INSPECTION OF IRON AND STEEL.

[Continued from May number.]

WHAT IT ACCOMPLISHES.

WE HAVE seen how inspection has developed from small beginnings to its present state and the methods now in use among first-class inspection bureaus. But what does such inspection accomplish? What does it amount to, and why is it necessary, or even desirable? It is necessary for the same reason that a superintendent, or clerk of works, is necessary during the construction of a building; simply because the millennium has not yet been reached in this world in which we live; because men will always work first and foremost for their own interests, and some men do not realize that their own best interests lie in turning out the best work they know how. Inspectors work for their own interests just as faithfully as anyone else, but their interests lie in serving to the best of their ability their employers, the engineer or architect in charge of the work they are inspecting. They do not look for remuneration to the bridge company or the rolling mill. They have no reason for passing an error or for overlooking a bad job, and hence there is no temptation for them to do so. Inspection furnishes means by which the engineer or architect may know that the work in his charge is being done as he wishes it done, that the specified amounts of material have not been decreased nor increased, and that the resulting structure is as strong and durable and efficient in every way as he intended it should be.

It is often easy in walking through a bridge shop to tell at a glance which of the various pieces of work in progress are in an inspector's care and which are not. The difference is often apparent to a casual observer. Some bridge companies make it a rule to plainly mark on all their working drawings whether the work is to be inspected or not, and by whom. In this way the workmen have the best of means of estimating the chances of bad work passing unnoticed. The excuse is sometimes made by a shop foreman, when a blunder or careless workmanship is called to his attention by an inspector, "I was not told that this piece of work was to pass inspection."

It must be conceded by all that there is a vast difference in results between good and bad material and workmanship. If there were not, the carefully written specifications as to quality would be superfluous. Accepting this fact, then, what becomes of the material manufactured for a particular piece of work and rejected by an inspector on account of poor quality? Such material is nearly always rolled in standard shapes that can as well be employed on one piece of work as on another. Is it all thrown out on the scrap heap and counted as so much dead loss to the manufacturer? Will the manufacturer even take the trouble and bear the expense of breaking it up and remelting it to correct the defects in its composition, if he can use it in any other way that will cost him less? Most assuredly not, unless it is so very bad that he cannot use it without grave risk to himself. He will think that the material, though not good enough to meet the "too rigid" require-

ments of that particular job, is still good enough for other work, and he will use it whenever he gets a chance; whenever he knows that the work will not be inspected.

Some of the bridge companies habitually omit washers as superfluous under the nuts of turned bolts, thus bringing a bearing stress on the threads. One company used three-quarter inch rivets throughout a structure where seven-eighths inch rivets were required and specified; and, when attention was called to the matter by the inspector, claimed that an error had been made in the shop. In another shop, upon work the specifications of which required that all sheared edges of plates must be planed to remove the incipient cracks produced by the shears, the workmen were found complying with the specification by taking so large a cut in the planer that great chunks of the metal were being literally torn off the plates, leaving the edge looking like a section of a plowed field. Carelessness is often encountered in foundry work where cast iron columns are produced. The cores are allowed to become displaced, resulting in columns with twice as much metal on one side as on the other.

A bridge was built a few years ago, shipped to its destination by the bridge company, and nearly erected, before it was discovered that certain important parts necessary to complete it had been overlooked—had never been made, in fact. It was during the freshet season, and to save the bridge from being washed away, temporary members were devised on the ground and the span fortunately swung before the falsework went out. When the missing parts arrived, new falsework had to be built, the span jacked up and disconnected, and the new members inserted. Such blunders as this cost money. An inspector who knows his business and diligently attends to it can be the means of avoiding such blunders, and not only of saving his employers time and trouble, but the bridge company of the expensive results of errors.

The employment of competent inspecting bureaus becomes more and more general as the iron and steel industry increases in volume and competition between the manufacturers grows keener. Men are realizing more and more forcibly the necessity for such services in order to insure good results. The day when people thought that because a bridge was built of iron it would stand till doomsday and support any loads that might be imposed is past and gone. So is the day when iron and steel was thought to be strong and durable because it was iron or steel. Men are finding out that there is good and bad iron and steel; and that there is such a great difference between them—often the difference between success and failure; between a strong, stiff and durable structure and an accident costing human life —that it pays to spend the small added cost to insure the use of the good material and to detect and exclude the bad. Nearly all the best structures built today are manufactured under the watchful eyes of inspectors employed to see that the provisions of the specifications are strictly followed.

But, unfortunately, this class comprises by no means all the structures built. There are great quantities of iron and steel structural material produced and made into bridges, buildings and other structures on which human life depends, that are not so inspected, and concerning which the purchasers have no assurance as to their strength or durability, because they have no knowledge of the quality of the material or of the treatment it has received

during its manufacture. Thousands of tons of steel are annually manufactured and sold to people who have no way of knowing anything about its quality. Hundreds of bridges and buildings are built every year out of such material, and no one can tell whether they will actually stand the strains they are intended to stand or not. Is the general public to blame when it assumes that such a structure is capable of successfully withstanding the loads and shocks it is called on to resist? Can a man do otherwise, when he enters a building or crosses a bridge, than place confidence and trust in the care and thoroughness with which its architect or engineer has attended to all the details of its construction? Accidents happen, much more frequently than they should, that are often traceable to bad material or workmanship; generally both. If the structure that collapsed had been inspected by competent men, such accidents would not have occurred. There is yet to be recorded a single case of a structure failing under the loads it was designed to carry that was properly inspected by inspectors who know their business and do it honestly; while, on the other hand, there are many engineers and architects who can testify to important saving of time and money through the employment of competent inspectors.

There are various reasons advanced why such inspection service is not employed. Most of them may be classified under the three classes discussed below.

First: Some people believe that, by placing their work with the best known bridge companies, they are so sure of satisfactory results that no check on the quality of the work turned out is necessary, and that, by availing themselves of such a check, they are casting unpleasant reflections on the honesty of the bridge company. This is far from a correct view of the case. It is not a question of the integrity of the bridge company or of its management; they may have the best of intentions. But what of the many men through whose hands or under whose eyes the tons of material must pass in its progress from the ore to the finished structure; each one of whom leaves the results of his work for better or worse upon it. Each man will look to his own personal interests first. It matters not to him if the material suffer so long as he can save himself from the consequences of the discovery of his bad work. Besides, it is human nature for a man to under-rate an error made by himself. His judgment is warped by his financial interest, and he is apt to think "it is good enough." Thus, when a man makes a mistake, or botches a piece of work, he is tempted to hide his error in order that his reputation with his foreman may not suffer. He knows that each error made *and discovered* lowers his value in his employer's estimation. Frequently employes are paid by the piece or ton, the workman then becoming practically a sub-contractor, with no interest in the work beyond doing it well enough to get his pay for it. His interest lies in doing a large amount of work—in the production of quantity, even at the expense of quality.

Foremen, and even superintendents, will frequently pass flaws and errors that their reputation for executive ability may be maintained. A manufacturing firm looks to its superintendent for results. Time taken to correct mistakes or replace faulty material means decrease of output, and if the output decreases, cost increases, and the superintendent must explain. So the work is hurried through the shop with speed of completion the principal end in view, and if the foreman or his superintendent notices a defect, he is

tempted to let it pass for the sake of keeping up the rate of output and saving the expense and time of correcting it.

Some shops maintain an inspector on their pay-rolls whose duty it is to examine the work as it comes from the shop and report errors. His duty is performed after the work is finished; he has no jurisdiction in the shop while it is going on. Errors committed and covered up are beyond his detection, and he assumes that they do not exist. But, even as regards the errors that may be discovered after a piece is finished, here, again, it is human nature for such a man to consult his own interests first and to perform his work in such a manner as best to serve the interests of the people to whom he looks for his pay. When he discovers a mistake in the fitting together of pieces, rivet holes left out of joints, or such like errors, he will report them; because he knows it will cost his employers much more to correct them in the field when they erect the structure than at the shop before the material is shipped to its destination. But he will be indulgent in such matters as loose rivets, buckled web plates, unannealed forged members, careless painting, and the details of construction that may be either good or bad without of a certainty causing his employers trouble later. He casts his lot in with the rest and risks the results, and that such risks are run, let accidents on record bear testimony.

Such an inspector is generally some man taken from the shop, some good mechanic, who can read a drawing and make an accurate measurement. He is paid little if any more than the men who are doing the work he is called upon to examine, and he draws his pay from the same window and standing in the same line with all the rest of his fellows. He probably belongs to the same labor union, and is closely associated, at all times, with the very men who are laying out the work, punching the holes and driving the rivets. It would not be good policy for him to be the cause of too frequent scoring of such men. It might be dangerous for him to be the cause of their discharge.

As to reflections on the honesty of a bridge company cast by the employment of expert inspectors by the architect or engineer, no company honestly trying to do good work has such a feeling for a minute. If the inspector knows his business, he will not interfere with the men at their work, nor will he cause the company unnecessary trouble in any way. He will be quick to detect errors and see to their correction; often his experience will be of material benefit to the foreman in suggesting the best method of making the correction. The inspector relieves the men from many cares in the performance of their duties, and the bridge company that has nothing to fear from the inspector will welcome him to the shop, because he helps them to see that their work is done in the best possible manner and to keep up their standard of perfection in the structures they manufacture.

Second: Some people think that the extra cost of inspection adds too much to the cost of the work. They prefer to pay the bridge company its price and run the risk of getting a poor job in return, rather than pay a slight excess to an inspecting firm and have assurance that they are getting good work. These same people will willingly pay a liberal premium in the stock market for bonds of good repute, rather than buy other bonds for less money; and yet the comparison is perfectly just. Is it not cheaper to pay $102 for an article known to be worth $100 than to pay $100 for an article that may not be worth $75? The cost of inspection, by competent experts who make

it their duty to watch every detail of the manufacture and check all the plans to see that everything has been done as the architect or engineer intended it should be done, should not exceed two per cent of the total cost of the steel work. Is such a percentage a high rate of premium to pay for the sake of security?

Not only is good inspection worth what it costs to the owner of a structure on account of the security he is warranted in feeling as to its efficiency, but it is a duty, owed by every corporation owning structures on which human life depends, to take every possible precaution to secure the safety of such structures. It is a good thing for a railroad manager to have inspectors' reports on file concerning his bridges. In case of accident to any bridge, and the often resulting damage suits, one of the first questions asked will be, "Did you have your work inspected, and by whom was the inspection performed?" Several recent suits resulting from accidents to bridges and buildings have developed the fact that no competent inspecting bureau had been employed during the construction, and the testimony has in every case reflected very unpleasantly on the carelessness or gross neglect of the engineer or architect.

Not long ago, in the construction of a railroad, a bridge was required across a certain stream. The railroad company had faith in the bridge company to whom the work was let, and saved the extra cost of inspection. Subsequent examination showed that not only was the work built at the very lowest limit of safety as regards design, but the material was dangerously high in phosphorus, careless shop work was admitted, resulting in the punching of clover-leaf rivet holes, and to crown all, a mistake in marking the pieces had resulted in the interchange of members, a light one being placed where the strain sheet called for a much heavier one, and vice versa. That accident cost the lives of three men, to say nothing of delays and expense in replacing the structure. Yet the railroad company justly felt itself lucky, for an excursion train had passed over the bridge but a short time before. It is remarkable, but not at all surprising when the truth is known, what a large proportion of the accidents occur to new structures.

Third: It is claimed by many that inspection, as it is generally conducted, is not effective; that the work is performed in such a careless, slipshod manner as to be void of the benefits it is intended to confer; and that money spent for inspection is practically thrown away.

Unfortunately, this has been but too true in the past. Inspectors worked carelessly and without system. Points which should have been detected were overlooked, and much of the work they were supposed to do was not done at all, or was so poorly done as to afford but little protection to the engineer or architect. Even now there are many who are performing their work in this careless way; undertaking to inspect a piece of work for about half what good inspection costs, and then giving the work what attention they can afford for the price, and no more.

Mr. J. A. L. Waddell, one of the foremost bridge and structural engineers of this country, has had his own troubles with inspectors, as may be seen from the following extracts from Chapter XXI of his excellent little book, "De Pontibus." That whole chapter is full of interest in this connection and will well repay careful reading. Mr. Waddell says: "For many years most of the inspection of structural metal-work was a sad farce; and, in consequence,

the general public placed but little confidence in inspection, with the result that a large portion of the bridge-work of the country was left entirely to the tender mercies of the manufacturers. Latterly, however, owing to the efforts of a few first-class inspecting bureaus, the status of inspection has been somewhat improved, although it is far from being today what it ought to be.

"The inspection business has been utterly demoralized in times past—for it was the general custom, and is yet to a certain extent with some inspectors, to take contracts for inspection at whatever figures the purchasers are willing to pay, then handle the work so as not to lose money on the contract, regardless, of course, of the interests of their employers.

"Strange tales concerning inspection come to the ears of engineers—such, for instance, as passing car-load after car-load of metal-work that was not seen by the inspector until after loading for shipment; but such tales need verification, which, of course, it is nobody's business to give them. In one case in the author's experience the inspector left his work for ten days in charge of one of the bridge company's shipping clerks, without notifying either the author or his direct employers, the inspection bureau, of his contemplated absence. Such actions as this make one entertain doubts sometimes as to whether inspection really pays."

Mr. Waddell evidently believes that inspection by competent bureaus does pay, after all, since he is one of the most careful engineers to see that all his work is inspected and that the rigid requirements of his specifications are strictly followed.

There are a few inspecting bureaus who are striving for the improvement of inspection services, through the establishment of carefully devised systems for the thorough handling of the work and the employment of only experienced and thoroughly reliable men. Such companies can and do give the quality of service that makes inspection thoroughly valuable. But they have thus far found themselves seriously handicapped by the many irresponsible inspectors who undertake work at ridiculously low prices without any idea of doing it as it should be done. Engineers and architects are not a little to blame for this state of things, since too many of them fail to consider the inspection service as one having degrees of quality. They have become accustomed to consider that all inspection is the same, and to require that each inspector who makes application for their work shall submit his prices in competition with anyone else who may be an applicant, and then employ the man with the lowest price, without taking the trouble to properly investigate the comparative facilities or reputations of the applicants.

It cannot be expected that the best results of inspection will be gained by crowding the price for such services down to the lowest possible figure. There is a limit below which good inspection cannot be performed. The only way that an engineer can get the full benefit that inspection can confer is to determine at the outset to pay a fair price for that service, and then, before appointing an inspecting firm, to look carefully into the reputations of the different inspecting companies available by references to other engineers and pieces of work that have been inspected by them.

Thorough and complete inspection of iron and steel structural material should generally be worth one dollar per net ton of shop shipping weights. At times and under especially favorable conditions as regards the location of a bureau's employes, it can be done for less. On some small jobs it may be

worth more; but there is, in general, a chance for the inspector to make a fair living at that average price. Such inspection should include the careful comparison and checking of working plans and complete supervision and tests, by thoroughly experienced, expert and reliable men, throughout the manufacture of the material, from the time it is first produced until it is shipped from the shop.

The most experienced engineers and architects already realize that only first-class inspection is valuable. These are taking pains to see that only first-class men are employed by them, and at a fair price. Inspection bureaus who enjoy the patronage of such men are doing all their work the best they know how, and are fondly hoping for the dawn of the day when the general public will recognize the value of the efficient service so rendered.

Good and thorough inspection can be had, but not at the low prices so many people seem to think it should be done for. If complete inspection, as above defined, is worth one dollar per ton, it cannot be expected that the man who refuses to pay that price will get such inspection.

Much of the success or failure of inspection depends on the individual ability and character of the inspector. Good inspectors are not easy to find, and, when found, they are worth more than the cheap bureaus can afford to pay them. A successful inspector must have a rare combination of good qualities. He must be a practical man, with long training in mills and shops. He must thoroughly understand all the details of the various processes employed and what are the various faults that are liable to result from each process. He must so well understand these faults as to be able to detect them at once, and he must be so well informed as to know how best to correct them in the most practical manner; and when correction is not possible. But experience in mill and shop practice alone will not suffice. He must also understand enough of structural engineering to recognize the relative advantages of different details and designs. He must be able to figure out the strength of the various connections and parts, and have accurate judgment to determine just what effect a loose rivet here or a bad fit there may have in the resulting structure. He must be quick to think and act, for he is the umpire, and his decisions must be prompt and fair, to be respected. He must, withal, be a good deal of a diplomat. The inspector who cannot deal with each mill and shop foreman in the way to best command his respect and secure his coöperation will never make a success. And, above all, he must be a man of most sterling character, straightforward, upright and honest. His is a position of no slight trust, and he must prove himself truly worthy of that trust at all times.

The inspector's life is not all sunshine. He has many a disagreeable duty, and, unless he has the necessary judgment and diplomacy, there will be much friction between him and the men in charge of the mills and shops where his work is located. But a good, sensible man, with the qualities of a good inspector, will gain his points without engendering bad feeling, will get over the rough places tactfully, and do his work quietly and unostentatiously, but effectively. Some day the public will appreciate how important his work is, and then the inspector and the inspection business will receive the respect it deserves.

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BUILDING IN REGARD TO EARTHQUAKES.

THE JAPANESE BUILDING SYSTEM.

WE HAVE heard much about the vaunted solidity of Japanese buildings during earthquakes, and to credit some persons, we should fancy that they were models in their way; but we think on the contrary, and it is our decided conviction that if earthquakes have not caused greater damage to Japanese buildings, the fact is due to their narrow dimensions, in height especially, rather than to the merits of their building system.

Japanese houses are all of wood; they have, as a rule, a rather low ground floor; the first floor, if there be one, is usually only seven or eight feet high; two-storied houses are rare. The following description will give a simple idea of their system:

They have little or nothing of foundations. They have a basement, or simple stone-supports on which stand the raising pieces, sustaining the posts, or they have blocks of stone on which stand the posts themselves supporting the raising pieces.

They have a small number of posts, and between them you have paper paneling. This has led people to say that Japanese houses have paper walls. And in fact all the inside of the houses, as well as the front walls, are so made, that when the sliding parts are taken away, there only remain the floor, some posts at distances, and the ceiling.

There are absolutely no joists or discharges either above or below the posts above mentioned.

There is a very heavy framework roof, made up of several tie-beams, or posts, without beams placed one above the other, on which rest vertical posts, without struts and with heights dependent on the slope of the roof. You have purlins at the end of these superposed tie-beams and posts; then come hips, rafters, battens, shingles, coatings of mud and lime, lastly heavy tiles.

Here is a concise sketch of a Japanese house, and you see from the description that it apparently offers some grounds of security against slight earthquakes, by reason of the rocking afforded by its looseness of structure; but we shall soon see that it is badly fitted to withstand strong horizontal shocks.

In the first place, the Japanese merely rest their buildings on the ground, without deep foundations, in order, as they say, not to offer any resistance to the lateral displacement of the building during horizontal oscillations of earthquakes. This want of foundations seems quite logical at first sight; but if we examine the question carefully we shall not so readily admit the possibility of finding an extent of surface smooth enough to obtain the desired effect in sufficient measure. We should rather think that by reason of the weight of the structure and the nature of the points of contact with the ground, it must be allowed that the building will follow, at least largely, the motion of the earth. In all cases, and according to Japanese principles,

these structures with raising pieces resting on blocks of stone would be preferable to those in which the raising pieces rest their entire length on a masonry basement. The advantages of the first system over the second would thus be proportionate to the extent of surface in contact with the ground.

It is to be presumed that the experiment of the sheet of paper which, when quickly withdrawn, can be taken from under a heavy object without displacing it, is quite to the point in the Japanese principle of the structure sliding on its foundation. But they forget that the object will be shifted if it be not done sufficiently quick, that is, if the velocity of the sheet of paper is not great enough.

Besides we can hardly admit that in an earthquake the horizontal oscillations or shocks can ever attain a velocity similar to that of the sheet of paper in the above experiment; and even if it should be attained in some cases, we should not forget that there are shocks, quite as ruinous, which have not that velocity, and that in most cases, if not in all, the house will shift from its foundation just as in the experiment of the sheet of paper, when the velocity is not sufficiently great.

Among other plans it was proposed at San Francisco to make wood buildings there rest on convex surfaces, and even on balls. We have also been told that in Japan they had built a lighthouse which rested on such balls, but that experience had condemned the system, and that the lighthouse had finally to be rebuilt on received principles. These different sliding or rolling systems are nothing else than improvements on the Japanese principle above treated, and it is easily understood that they can only be applied to light wooden structures and under peculiar circumstances.

We then conclude that if the idea of supposing a building to slide on its foundations has some appearance of logic, as a matter of fact it is a chimera, and from a practical point of view must be considered totally illogical. We think then that we must try and give to structures by more rational methods that security which is wanting in order to effectually withstand earthquakes of great intensity.

The want of joists and discharges to strengthen the assemblages of the posts with the raising pieces and with the upper framework is, in the eyes of Japanese builders, a consequence of the following principle. If, say they, we grant that our buildings should slide along the ground during the horizontal oscillations, it is yet to be feared that they will only do so imperfectly, and then the play of the posts in the assemblages compensates for the shortcomings of the former system.

Now, as among the Japanese, all is the result of the experience of several centuries, this requirement of doing away with joists and discharges proves over and above the insufficiency of the gliding principle of buildings on their foundations, although it shows at the same time that a certain elasticity favors the resistance to horizontal shocks. For would it not be more logical if the gliding took place easily to render the whole work more rigid, so that the structure should, and that by reason of its force of inertia, glide along the ground without any fear of giving way in the upper portions.

Many Europeans still believe that the Japanese make their roofs also very heavy with a view to the earthquakes. Our views, however, differ on this point, and it seems to us that the great weight of their roofs is only a result of their system of framework and roofing.

Imagine a framework in which there are no king posts, but only a great number of tie-beams placed one above the other, and of posts or uprights placed vertically, resting directly on the one side on the lower tie-beams and on the other side supporting the tie-beam directly above, then the purlins and finally the hips, in pavilion-shaped roofs.

The posts or uprights, as they have no struts, require, in consequence, strong assemblages, which thus necessitate very large dimensions for the tie-beams in order to afford the requisite strength.

Moreover, Japanese tiles, which are all hand-made, are frequently porous, and in consequence, require a certain thickness of materials (18 to 20 millimetres) so as not to be pervious to rain; besides, as these tiles are only as a rule about 255 millimetres high, and have no catch, you are forced to give them a large covering, even under a minimum slope of 30°, to obviate the inconvenience caused by capillarity. Their shape resembles the Mosselman tile, but they are much heavier, though smaller, the square meter of their tiled roofing weighing (the tiles only) about 60 kilos. Finally, their shape requires you to put them on a bed of fresh mud, in which the tiles are imbedded, so that they may not under the action of the wind and the vibrations caused by earthquakes slide about on the roof; in spite of that it frequently happens that the water filters through the tile, or rises in virtue of capillarity, so as to go beyond the roofing, or is moved away by the wind, and then the mud gets moist and ends by causing the shingles and battens to become rotten. That is why the battens have one or more coatings rather thick and capable of becoming sufficiently hard for the wet not to get through so easily.

All this arrangement cannot but be heavy, and the Japanese cannot, as far as we know, prove satisfactorily that heavy roofs enhance the solidity of a structure in respect to earthquakes.

From what we have said about Japanese houses, we see that as a matter of fact they are able to withstand earthquakes of slight intensity, but if we now try to realize how our Japanese structure behaves under the action of a strong horizontal shock, we have our doubts about its vaunted solidity. In matter of fact, we have seen above that the principle that the house should glide on its base, has no guarantee of security; we have seen, likewise, that owing to the want of joists and discharges, if the sliding does not take place, there will be an oscillation at the base of the posts. Now, if these oscillations be strong, sudden, and of some amplitude, will there be no reason to fear that in virtue of the inertia of the large mass of roofing, and of the great velocity of the ground oscillation, the assemblages should come to grief, and that the structure should go to pieces like a house of cards?

We know that inertia is proportionate to the mass and velocity $\left\{ \frac{1}{2} M V^2 = \frac{1}{2} \frac{P}{g} V^2 \right\}$ consequently if in the case under consideration the weight of the roof be heavy, and the oscillation be also great, it will necessarily follow that the strain on the assemblages of the posts will be enormous, so that they will give way, if sliding does not take place, and the result will be that the structure will crumble to pieces.

At all events, the increase of weight in the upper rather than the lower portions of the structure cannot but increase the danger during the hori-

zontal oscillations. This is, besides, our impression after the experience of a good number of earthquakes, and we feel more confident in a house which is heavy at the bottom and light at the top, but solid and properly planned.

What we have said about Japanese houses applies to Japanese palaces and temples; we find the same principle and the same system everywhere, with only this difference, that temples and palaces are larger and built in proportion more solidly than ordinary structures.

We have been speaking hitherto of horizontal oscillations only, because they are evidently more dangerous, at least for wooden structures. But earthquakes often have vertical oscillations, undulations, gyrations, at times all these different motions together.

The precautions against vertical shocks are, as a rule, of the same nature as those employed under ordinary conditions in order to render a building as strong as possible; that is to say, very thick walls, very solid foundations, materials of a very good kind and able to resist any crushing, and above all a perfect arrangement of the different parts of the building, especially the floor and other horizontal parts, the elasticity of which could do considerable damage to the adjacent walls during vertical oscillations.

As all the other motions of the ground are only combinations of the horizontal and vertical oscillations, we may take it for granted that if all due precautions have been taken against these two kinds of motion, the building will be as solid as possible against the other motions of undulation, gyration, etc. We may notice that in almost every case the extent of surface taken up by a building as compared with the amplitude of an undulation is generally small enough to entitle us to consider the foundations of a building as resting, to a certain degree, on a plane surface, if not always horizontal, at least vibrating or oscillating as a piece. And in support of our opinion, we shall quote an account for which we are indebted to the kindness of Mon. H. Pélegrin, Engineer of the gas manufactories of Yokohama and Yedo. For the three years and more since gas has been used in those towns, the underground cast-iron pipes have not indicated the slightest escapement which could be ascribed to an earthquake; and yet more than 35 kilometres of cast-iron pipes are laid in Yokohama and nearly 20 in Yedo. We must admit, however, that it is impossible to safeguard buildings against earthquakes in which the ground cracks or produces similar effects.

Fortunately such catastrophes are comparatively rare, and we have generally only to fear earthquakes of smaller intensity, but yet intense enough to overturn strong buildings constructed after the usual methods.

Before speaking of masonry buildings, we shall say a few words about a cheap method of building in wood. Besides its many other advantages, it offers a very great security against earthquake.

It is this: To set pans of wood, with very large openings and pugged with well made brick or ashlar work. Then to consolidate the principal assemblages by joists, bolts, braces and iron plates.

But you will object, no doubt, that if the masonry walls on the outside are not covered over with very impervious coatings, they will be constantly penetrated by the wet, and in consequence will become unhealthy, while they will at the same time help to rot the wood with which they are in contact. For, as a matter of fact, in the pans of ordinary wood the portions in brick

work will never exceed in thickness the length of the bricks, say about 22 centimetres; and we know that a brick wall of this thickness is usually very damp, and that it is even difficult, in some countries and climates, to render it altogether impervious.

We shall then notice a method which we have never seen employed in Europe to keep off the damp both from the piece of wood as well as from the pugging, and thus make a building in wood as healthy and comfortable as solid.

On the outside of the walls nail diagonally or crosswise laths, about 8 to 10 centimetres broad and 2 centimetres thick.

On these laths nail a kind of flat tile or terra-cotta flagstone, at times varnished. The Japanese call it *tata cavaza* (a tile which lies or stands; a coating tile). While making these tiles you must leave a small hole at each of the angles for the nailing. It is usually 30 centimetres square and 2 or 3 centimetres thick.

Then cover the whole with several layers of coating. The Japanese often merely grout the tile a greater or less number of times consecutively.

It will be readily admitted that the layer of air 2 centimetres thick, which is between the wall and the flat tile or coating flagstone, is enough to prevent the damp from getting completely to the walls. We have seen very old Japanese buildings in which the laths themselves had remained whole enough.

The foundations will be made according to the ordinary rule and without concerning yourself about the sliding, which may not be possible, of the building on the ground or on its foundations during an earthquake.

The roofing will be strong, but as light as can be.

You have here a cheap construction, which appear to us the best and most serviceable for almost all the colonies, whether subject to earthquakes or not; for, besides the solidity, it has the advantage of being very healthy and comfortable. It is better than the ordinary buildings in wood, being proof against fire, heat, cold, etc., and in the event of an earthquake, it is stronger than those horrible masonry buildings.

MASONRY BUILDINGS.

We have hitherto been treating of masonry buildings; and what we have said about Japanese buildings gives a sufficient idea of the way in which the Japanese dispose the framework of their houses to protect them against the ruinous effects of earthquakes. The preceding pages will probably prove interesting to those builders who are busy with wood building in countries where there are, or, where there is, fear of earthquake.

But we consider it of interest to say a few words as well on masonry buildings in general, considered from the present point of view.

As a general rule, the best masonry building is one in which the materials and the connecting cement which keeps them together becomes adhesive enough to give the collection of walls some approach to the consistence of a *monolith.*

Here is evidently a case in which we can put no trust in the Japanese principle of the structure sliding on its foundations on account of the great weight of the masonry and the large surface for friction of the base of the walls. It is then decidedly more reasonable to fix, as we do, the building on the ground, and to raise it on strong foundations; to make of it, in a word, a *rigid* building, heavier at the bottom than at the top.

When we employ the words monolith and rigid, we don't mean to disregard the elasticity which all brickwork possesses in a greater or less degree, for this elasticity is evidently indispensable, especially in cases of the sudden shocks and jerks often experienced in earthquakes. As brickwork keeps its elasticity best, in virtue of the multiplicity of connections, we have even preferred this mode of building in the different works entrusted to us in China and Japan.

In an earthquake felt at Fowchow, China, in 1867, we saw from our first story, and literally under our eyes, a closing wall of brickwork about 15 metres long, 2 metres high and of the depth of a brick, and which was entirely separated at one of its ends, oscillate at the end separated to an appreciable extent of 8 or 10 centimetres right and left of its normal position. We may at once remark, that as we ourselves were in motion, our appreciation might be incorrect, so that the figures given need not be taken as absolutely correct. However, after the earthquake there was no trace of a break either in the bricks or even in the joining. It is true the brickwork was rather badly made, the joinings were very thick and the mortar was of a very ordinary kind, and it may very well be that had the brickwork been better, and more of a monolith, it would have resisted this series of shocks of large amplitude less well. The house in which we were was built of brick, with window and door casings of stone. The brickwork resisted, but there were several fractures in the stone portions.

It is then clear that a certain elasticity is very convenient, and that a homogeneousness as perfect as can be is one of the requisite conditions.

Although brickwork has the advantage over masonry of the thicker specimen material of great elasticity on account of the very large number of joinings, we must not forget, however, that in the event of vertical shocks it is above all the resistance of the material to the pressure or crushing that must be considered. It is thus also necessary for the bricks to have great resisting force.

We shall describe at the end of the study our system of iron braces, applicable to masonry work, by the aid of which we can build with the thicker specimen material as well as with brick.

It is only a few years since brickwork has been adopted in Japan (at the arsenal of Yokoska, about 1867). The Japanese either do not know anything about bricks, or, at least, they do not use them for building purposes. So also they did not use stones except in the basement flooring, or merely to cover the outside of the wood paneling of some warehouses. It would then be rash on our part to pretend to establish now and conclusively that strong, well-made masonry work offers better resistance than the best woodwork. On the other hand, earthquakes have been comparatively less intense in Japan for the last twenty-two or twenty-three years, and very fortunately similar experiments can only be made in a very restricted number of countries. Thus, if this important question has been decided in other countries, in Japan it cannot be decided yet, and we prefer to come back upon information gathered elsewhere than to expose ourselves to mistakes, which are always fatal in these cases.

However, many of our brick buildings have already stood rather violent earthquake shocks, and have appeared to offer better resistance than similar structures in wood.

Nevertheless, we have not given over our studies regarding the method to add to the strength of masonry structures, for we could not evidently take too many precautions in order to preserve, within the limits of possibility, our dwellings against the ruinous effects of earthquakes.

We are equally aware of several manufactory chimneys in Japan which are built of brick, with or without exterior iron braces, and they all have up to this offered perfect resistance to earthquakes; and still these chimneys are excellent specimens of what we mean. They are solidly fixed to the ground, and are much lighter at the top than at the bottom; they have also a very marked elasticity by reason of their height, and their homogeneousness is sufficiently good.

We shall content ourselves for the present with these general considerations on masonry buildings, because in the following pages will be found the required supplement to what we have already said.

—*Lecasse, in Indian Engineering.*

[*To be continued in July number.*]

Timely Topics.

GOVERNMENT OF INDIA, FINANCE AND COMMERCE DEPARTMENT.

Specification of wrought-iron work of Bridges, Trusses, etc.

MATERIALS.

The wrought iron is to be well and cleanly rolled to the full sections shown on the drawing or in the specification, and free from scales, blisters, laminations, cracked edges, and defects of every sort, and the name of the maker is to be rolled or stamped on every piece.

2. It must be of such strength and quality as to be equal to the following tensional strains, and to indicate the following percentages of contraction of the tested area at the point of fracture, and percentages of elongation.

	Tensional stresses per square inch.	Percentage of contraction of fractured area.	Percentages of elongations in a length of 10 inches.
	Tons.		
Round and square bars and flat bars under 6 inches wide ---- ----	24	20	15
Angle T or other bars, and flat bars 6 inches wide and upwards - ----	22	15	12
Plates -------- --	21	10	8
Plates across grain	18	5	4

The rivet iron must be of such a quality that any rivet will stand the following tests without showing signs of failure:

Bending double upon itself while cold.

Bending double upon itself while red hot.

The shank being nicked while cold and bent double, showing the fiber of the iron to be of good quality.

Flattening down the head while red hot until its diameter is equal to 2½ times that of the shank, without showing any signs of cracking at the edges.

Punching through the shank when at a red heat, with a taper punch, a round hole the diameter of the rivet, without showing signs of cracking or splitting.

The tests are to be conducted at the works of the contractor or elsewhere or both, as may be determined by the inspecting officer. The expense of the tests is to be borne as provided for in the conditions of contract.

No material is to be used which, in the opinion of the inspecting officer, falls short of the tests and other requirements of the specification, and no iron except of British or Indian manufacture is to be used throughout the contract.

Firms tendering are required to submit with their tenders the names of the manufacturers, and the market name of the iron they propose to use.

Manufacture.

3. It is to be expressly understood that the greatest accuracy is to be observed in every part of the work, a main object of the designs being to facilitate as much as possible the erection of the work by perfection of workmanship. All corresponding parts of all spans or trusses must be made exactly similar and interchangeable.

4. All plates and bars must be rolled to the full sections and the angle T channel or other bars to the full widths and weights per foot, shown on the drawings. All bars which do not hold their full widths and weights from end to end, or which have rough, jagged, or imperfect edges or ends, will be rejected.

5. All plates, flat bars, and angle T channel or other bars must be carefully levelled and straightened (the angle T channel or other bars by pressure and not by hammering) before and after they are punched or drilled. All edges of all plates, and the ends of all angle irons and bars, must be planed dead true to the dimensions, or, where planing is impossible, they must be dressed off fair with hammer, chisel, and file. No rough

edges fresh from the shears will be permit'ed anywhere throughout the work.

6. All rivet holes to be filled in the field are to be ***drilled.***

All other rivet holes may be either drilled or punched, at the option of the contractor, but any plate or bar in which the holes are not accurately in place will be rejected. The holes through which any one rivet passes must correspond in any number of plates or bars.

Although the word "rivets" may be used on the drawings, the rivet *holes* are to be made the sizes figured, and in no case must the diameter of the rivet be more than $\frac{1}{32}$ inch less than the diameter of the hole it has to fill. All loose rivets, and rivets with cracked, badly formed, or deficient heads, must be cut out and replaced by others. Rivets must also be cut out when required for the examination of the work. All work intended to be riveted or bolted together must be absolutely in contact all over the whole surface.

All rivets, unless otherwise specified, are to be cup-headed at each end, and the heads are to contain not less than 1¼ diameters of the rivet.

Whenever necessary for the division of the work for transport, the rivets are to be left out, but the holes in all cases must be drilled ready for riveting, and all the requisite rivets, including the spare rivets, must be sent with the ironwork.

7. In all cover plates, except in web of plate girders, the fiber of the iron must run in the direction of the length of the span.

All plates must be shaped to the full sizes shown on the drawings, and any plate in which the rivet holes have been drilled nearer to the edge than shown on the drawings will be rejected.

Where cover plates are used to connect plates of different thicknesses so much of the covers must be planed down as will make them fit fairly over the joint, no packing plates being allowed. The figured dimensions on the drawings show the different thicknesses after the cover plates have been planed down.

8. The main girders of all spans above 20 feet are to be built with a camber in the arc of a circle, the upper members being proportionately longer than the lower. The extent of the camber is in each case figured on the drawing.

The ends of all plates, etc., must be chipped and filed so as to butt with perfect accuracy over the whole of the meeting surfaces to the true radius necessary for the specified camber, and any joint which fails to form a perfect butt all over will involve the rejection of the length or lengths of the members which cannot be made to fit without being shortened.

Girders of 20 feet span and under are to be without camber.

9. The underside of the bearing plates of all main girders must be perfectly level and the rivets countersunk.

All bed plates are to be absolutely flat, and the guiding edges planed and truly parallel.

10. All bolts are to be screwed to Whitworth's standard thread, and all nuts must fit too tightly to be turned by hand. The heads and nuts for all timber bolts (except where otherwise shown on the drawings) and service bolts are to be square; for other bolts they are to be hexagonal.

The head and body of all bolts are to be forged out of one piece of rod or bar iron. All bolts are to be screwed for a length of three diameters.

Completion of Work and Erection.

11. All the spans are to be temporarily erected complete, so that accuracy of fit and perfection of workmanship may be assured.

As the work is erected, all the holes which are left to be riveted in the field must be filled at one and the same time by temporary bolts 1-16 inch less in diameter than the holes which they fill firmly screwed or keyed up. It will not be sufficient that bolts shall be placed in a certain number of holes only at a time, nor will it be sufficient that only such a number of bolts shall be inserted as may temporarily hold the span together.

Painting, Marking, etc.

12. The whole of the ironwork, with the exception of the bolts and rivets, is to be scraped perfectly free from rust, scale, and dirt, and then brushed all over with boiling hot linseed oil. It is afterwards to be painted with two coats of good oil paint, the first being of red lead and the second of Roman ochre, or other colors to be specially approved by the Inspecting Officer. Wherever plates or bars are to be riveted together, the surfaces that will be in contact are to be thoroughly cleaned immediately before plating, and one of them is to be covered with a good coat of red lead paint.

One end of every case is to be painted the same color as the span for which its contents are intended.

The bolts (including the service bolts) and rivets are to be heated to the temperature of melted lead; and then dipped into boiled linseed oil.

13. Every portion of every span is to be very distinctly stenciled with paint and marked with the punch for guidance in erection, and every piece or bundle of iron is to be similarly marked, and every packing case branded, with such marks as the Inspecting Officer may require.

All parts of the work are to be stamped with the letters "I. S. R.," or such other letters as may be ordered.

A neat casting bearing the name of the manufacturer, with place and date of manufacture, is to be bolted conspicuously on every span of main girders, and on every truss.

ELECTRIC POWER IN WORKSHOPS

The greatest achievement of the century which now approaches its close is the intimate connection that has been established between science and practice, the effects of which are noticeable in every feature of modern civilization, and in none more than in electrical engineering.

A little over thirty years ago the dynamo-electric machine was invented, which made electrical engineering of practical utility; but long before that time the laws of Nature had been discovered by scientific research, which govern the flow and the distribution of electrical currents, Ohm's and Kirchoff's laws, and which permit of the accurate measurement of the same, Weber's, Ampère's, and last, but not least, Faraday's researches.

In no other domain of human activity has it ever been possible to attempt the solution of problems with an equal certainty of being able tc criticise the proposed methods by the light of well-established scientific rules, and of avoiding unnecessary trouble and expense when these rules showed an error in the reasoning. This facility of verifying results accounts for the rapidity of the progress of electrical engineering and for the variety of purposes to which electricity is nowadays applied. Among these, transmission of power promises to become one of the most important, and it may not be uninteresting to study its development a little more in detail. Although telegraph instruments and indicators generally belong, strictly speaking, to this branch of the subject, the term "transmission of power" is usually only applied to cases where electric motors are employed to convert electrical energy into mechanical motion.

The first important development took place in connection with electric tramways, starting from the small circular line exhibited in Berlin by Dr. Werner Siemens in 1879.

With our present experience there is no need to dwell on the advantages of electric traction in the streets of towns and their suburbs, and there is little doubt that in the near future horse and steam tramways will disappear everywhere. Up to now cable traction has held its own in all cases, where exceptionally heavy gradients have to be dealt with, but means are devised to overcome such gradients with the help of electric motors, and in this field the ultimate triumph of electricity is also assured. This great success on tramways has naturally led to attempts to move the trains on the railways by means of electric locomotives, and it is well known that even the heaviest goods trains can be drawn by electric motors as well as by steam locomotives. It would be a fallacy, however, to deduce from this fact the conclusion that it would be advantageous to replace the locomotives on all existing railways by electric motors, as the feasibility of such changes depends ultimately only on economical considerations. The changes may be technically possible, but an alteration can only be introduced if a saving in expense is thereby effected. This principle governs not only electric traction, but the whole field of human progress, which proves the necessity of investigating the economical aspects of a problem after its scientific features have been examined and found to be based on sound reasoning.

In the case of transmission of power there are three factors, common to all systems, which determine the cost of the motive power at the place where it is utilized, and thereby indicate what is the proper system to use.

The first factor is the source of the energy that is to be distributed.

The second is the means of transmitting; and

The third, the apparatus for utilizing the energy.

With regard to the first point, the electric system is hampered by the fact that the available mechanical energy, however produced, has to be converted into electrical energy, and such

a transformation always involves losses, which are avoided where the mechanical energy can be applied direct to the means of transmission.

As the cost of generating electricity decreases up to a certain point with the increase in size of the dynamos, it is desirable so to arrange the whole system that the units of the generating machine can be constructed large enough to give the most economical results, and so to choose the site of the generating station that all the necessary supplies can be obtained in the cheapest manner.

In spite of the drawback mentioned above, electric transmission of power is applicable in a great many cases on account of the unquestionable superiority of the means of distributing electricity over the means of dealing with any other form of energy. The ease with which the current can be carried over a long distance, the certainty with which the losses can be determined beforehand, and the flexibility of the conductors, constitute advantages which no other system presents; while the inevitable loss of the double conversion, added to the losses in the conductor, militate against the application of electricity in cases where the source of power and the apparatus for utilizing the same can be brought close together.

As the efficiency of electric motors has been accurately determined, there is no difficulty in predicting how much of the mechanical energy produced by the original source of power is available for useful purposes, and it is easy to ascertain, from time to time, that the desired electrical conditions are maintained.

It is well known that over 84 per cent of the indicated horse-power of a steam engine is available at the terminals of the dynamo in the form of electrical energy, and that electric motors will produce over 90 per cent of the electrical energy supplied to them in the shape of mechanical power. These high efficiencies were obtained at a comparatively early period, and it was, therefore, obvious that the main advancement of the electric system must be sought in diminishing the cost of the conductors without increasing the loss of energy during transmission. Guided by the teachings of science, nearly all inventors have attacked this problem by suggesting an increase in the pressure of the current in one form or another. Under the impulse of this tendency the art of insulating electric conductors has steadily improved, and while it was not long ago considered impracticable to work with currents of more than 2,000 volts pressure, there are now a number of successful electric systems employing currents of 10,000 volts pressure, and insulated conductors for even higher pressures can easily be obtained in the market. More serious difficulties appeared when attempts were made to construct dynamos and motors for high-pressure currents, and many ingenious devices have been suggested to overcome or to avoid them.

In the case of alternate currents the employment of transformers permits the use of low-pressure generators and motors, while high-pressure currents transmit the energy through the conductors; but this advantage is obtained by introducing another loss through the double transformation. Without much explanation it is easy to understand that the advantage of such a system is the greater the further the source of power, and the motors are distant from each other. Another advantage of this system is that the transformers have no moving parts, so that they require next to no supervision, and they do not occupy much space. If an equally reliable alternate current motor had been invented, there is little doubt that this system of transmitting power would be the dominating one at the present time, but unfortunately alternating current motors up to now refuse to start without being first synchronized by external means, they are liable to stop abruptly, when they are overloaded, and their speed cannot be varied.

A great step towards the solution of the problem was made when the possibility was discovered of combining three alternating currents in such a way that return wires can be dispensed with. This result is brought about by employing three alternate currents with their phases differing by 120 deg., so that their sum is at every moment zero. At the same time a revolving magnetic field is produced in the field of the motor, so that its armature can start revolving without being first synchronized.

In certain cases it is not even necessary to supply currents to the armature, in which the currents will be induced by the revolving magnetic field, so that all difficulties of making contact with the revolving part of the motor are avoided.

As in the case of single-phase alternate currents, stationary transformers can be used with three-phase currents, which, therefore,

present very conspicuous advantages for transmitting power. On the other hand, a continuous current system is decidedly simpler, and consequently cheaper in first cost and cheaper in maintenance, provided the dynamos and motors can be well enough insulated to permit the use of high-tension currents. The transformation losses are avoided, and the motors can be made extremely efficient for large differences in their load, and their speed can be varied without much trouble, both qualities in which the three-phase motors are deficient.

As there are continuous current-generators regularly supplying currents at more than 2,000 volts pressure, it is evident that this system can be applied in all cases where the distance between generator and motor is not excessive, and indeed, in most cases where electricity is employed to distribute power in factories, continuous currents are preferred. Such an installation, viz., the electric plant at the works of Siemens Brothers & Co., at Charlton, was described by the author in December, 1894, before the North of England Institute of Mining and Mechanical Engineers, at Newcastle-on-Tyne, and since that time very valuable experience has been gained there with regard to the suitability of electric motors for driving machinery.

Six years' work has shown that the system is perfectly reliable, and that the expected great saving in the cost of attending to the motive power has been fully realized.

During the year 1897 the output of the generating station was 1,178,286 B. T. U., or a load factor of .18.—*Alex. Siemens in Eng. Mechs.*

EXPERIMENTAL STUDY OF METAL BRIDGES

The importance attached by the Dutch government to the building and keeping in repair of metal bridges has occasioned considerable comment. For several years a special corps of engineers has been detailed to oversee and report on the condition of the superstructure of the railroad bridges, and in this they employ experiments very largely.

In Belgium, too, attention is being paid to the matter of metal bridges, but Holland remains far ahead, as will be easily seen from a glance at the work done in the latter country during the past two years.

The following particulars we have culled from the communication attached to the report of the Council for the Management of Railroads for the year 1897. The communication in question was read by Engineer Schroeder van der Kolk before the Institute of Engineers at the Hague.

During the year 1896 experiments were made notably on the bridges of Moerdjik, Hollandsch Diet, and Bommel over the Wahal.

The records of the Moerdjik show that the girders offer sufficient resistance for the regular traffic of ordinary trains, but that it would not be safe to permit the passage of very heavy loads—say, for instance, of cannon—without strengthening a diagonal and adding two counter diagonals in each panel of the truss.

Careful investigations have developed the existence of numerous cracks in the angles which join the stringers to the cross-beams. These cracks have been attributed partly to lack of strength in the angles, partly to the action exercised by the horizontal stays by which the diagonals are fixed to the stringers.

The strength of these pieces has the effect of causing the stringers to participate, in a certain measure, with the lengthening of the ties of the girders. The tension thus produced in the stringers is still more increased by the frequent horizontal bending of the cross-beams.

According to the plan for strengthening which has been elaborated, the cross-beams should be strengthened by the addition of plates upon the upper and lower flanges, and thus the action between the stringers and the bars of the stays would be eased.

As far as the members of the girders are concerned, the observations made at the Bommel bridge have led to the same conclusions.

Among the bridges visited and tested during 1897 are the following in particular: Ruremonde, over the Mense; Rotterdam, over the Konigshaven, and that of Liempde, over the Dommel.

As a result of the inspection of the Ruremonde bridge, certain modifications were made in one of the four arches. The succeeding tests were made with the object of ascertaining the effects of the alterations made. The following results were noted:

The strengthening of the cross-beams, obtained by the addition of plates upon the upper and lower flanges, does not exercise any

marked effect upon the lateral bending of the bars of the bracing of the beams.

On the other hand, by connecting the exterior and interior bars of the diagonals of the central part of the bridge, by strengthening a set of the diagonals, and by then adding a set of new counter diagonals, the strain on the main diagonals has been in a great measure reduced.

On the bridge at Rotterdam over the Konigshaven, it was observed that in the fixed spans, a great number of the angles in the flanges of the stringers were split, some entirely and some only partly. In order to take away all danger of accident, the position of the track was entirely modified, in such a manner as to remove the weight entirely from the stringers.

Observations showed that because of lateral bending the strain on the stringers is particularly great in the extreme sides of the flanges.

The stringers of the bridge at Rotterdam are of steel, and the discovery of the cracks has caused some distrust of this metal. Consequently several bridges, of which the cross-beams and stringers are also of steel, were visited and examined with particular reference to this point.

In the Liempde bridge the main girders are constructed after the Pauli system. Very large strains were observed in the extreme portions of the ties, and it was seen that the strain was the result of the irregularity of the cross-pieces. In place of crossing upon the vertical posts, as was provided for in the plan, the axes of the ties crossed at some distance therefrom.

At the end of 1897 the corps for the inspection of metal bridges was provided with thirty sets of improved instruments.

They possess eighty tension indicators of the system Manet. The department Ponts et Chaussées of the Belgian government owns twenty-four Manet-Rabut instruments.

Another improvement of the instruments in question is now under consideration. As is well known, the French instruments of this type only indicate, but do not register the tension strains. The Dutch apparatus, on the other hand, registers the maximum strain caused by the passage of a train. That is an improvement from the point of view of the student, but it is not sufficient.

The strains thus measured in the different machines do not correspond with the strain caused by a moving train, and that renders very difficult a comparison of results obtained.

The ideal register would be the one which would record continuously the strain produced at each instant by a weight in motion. It would then be very easy to find the position of a train corresponding to each recorded strain.

This problem has been solved as far as bending is concerned by means of the register of the system Richard-Rabut. The apparatus invented by the Dutch engineers for the measurement of the strain is based on the same principle.

The records of the instrument are received upon a band of paper wound around a cylinder which rotates regularly. The four strain-indicators are mounted upon the four edges of a piece in the same section, and are so arranged that the rotary movement is given to the four registering cylinders by the same clockwork.

The new indicators are said to be now completed, and some of them to be already in use. The preliminary tests, it is said, have been quite satisfactory.—*La Revue Technique.*

Editorial Opinion.

The Erection of Railway Bridges to replace those in use, necessitates the carrying of traffic during the progress of the work. That there have been few accidents from this cause is due no doubt to the care of the railway engineers in charge of the various roads. On some smaller lines, where there are no engineers of maintenance of way, the construction companies alone are responsible for the temporary trestle work which carries trains as well as the bridge itself. In some instances where the work is taken very low every endeavor is made to reduce the cost of the work by cutting down at every point, and among other things the false-work timber is supplied very sparingly, both as to the number of pieces and as to size. In one example at hand a saving in the cost of the false work was made of about fifteen per cent, but before the work was completed the false work was so out of shape that expensive hydraulic jacking was necessary to put things to rights and it is certain that the ultimate cost was more than it would have been if the false work had been of the proper design. That no accident resulted was due to chance more than anything else.

Many of the bridge companies have engineers of erection and the erection is as carefully carried out as any other portion of a contract; but there are too many who leave the "guessing" of false work and erection to an experienced foreman, who is no doubt expert at putting up metal work, but has no idea as to how to arrive at the sizes of the various pieces of timber by calculation.

The erection of highway bridges seldom involves the carrying of heavy traffic, and chances are often taken in proportion.

The exactness which pervades the work of bridge engineering should prevail in the carrying out of the erection of every structure, large and small.

Proposals for Railway Bridges are usually based upon data furnished in more or less complete shape by the railway companies or their consulting engineers. In some cases this consists of merely the general dimensions of a structure accompanied by a general specification; some roads furnish a complete stress sheet and accompany this by the specifications; others supply a stress sheet, a general drawing or design and supplementary specifications; while still others furnish complete detailed shop plans, with specifications for material, workmanship, painting and erection.

The first named calls forth a great variety of talent, obtains a variety of designs, good, bad, and indifferent, causes a waste of much expensive work and after much trouble in making a selection of the best bid, it is never sure that the best has been obtained. The second class obtains more nearly what is desired, at some saving in total work, but there is nevertheless much trouble in getting the details designed satisfactorily when the contract has been let. The third class of roads meets the situation in a manner nearly as satisfactory as the fourth, inasmuch as there is but little work required in making up the estimates by the bidders and the details are definitely fixed. The fourth method if persisted in until the shop costs of the various bidders became adjusted to the new conditions, so that the railways would get the benefit of the labor saved, in a lower price, is the ideal one, with the addition of the railway company stating a guaranteed weight when lump prices are wanted, or else asking for pound prices.

One large railway company which followed the fourth method some years ago, abandoned it for the reason that no lower prices were received when complete shop plans were furnished by them, than when the second method was employed. A different result would be had, however, if all the large railway companies could agree upon making their own plans to the usual shop forms, and allow a chance for the readjustment of the situation.

There would eventually be a great conservation of energy, a great financial saving, and

a beginning made in the reorganization of some of our top-heavy industrial methods.

Wooden or Combination Bridges and timber trestles are still being used extensively on new railway lines in the West, including extensions of some of the trunk lines. Those in charge of the work have no doubt fully satisfied themselves that from the financial standpoint this is the proper thing to do. The rates of freight to the far West being high, are an important factor in arriving at such a conclusion, especially in localities where timber is at hand in such quantities that it can be obtained cheaply. This difficulty could be overcome to some extent by the railways themselves, if they would agree upon a low rate for bridge material at times when there is a large movement of empty cars to the West. This is virtually done by the lines which reach Chicago, and are thus enabled to make the haul on their own lines to the bridge sites. Lines which do not reach Chicago, but are competitors of those that do, are placed at a disadvantage and cannot attempt so high a standard in the construction of the permanent way.

The engineers of such lines should take into consideration that the best constructed lines are the ones which will receive not only the passenger traffic, but a large percentage of the freight traffic as well.

It is not always a question of present saving, but of ultimate economy, and if the desirable low freight rates cannot be arranged for, it may be best to spend the additional amount for freight as well as a greater price for the steel bridge material over the cost of wooden structures.

The Real Low Bidder is not always the one whose figures are the lowest. A very flagrant case has just come to our attention where the amount of the contract would reach about sixty thousand dollars, and the lowest bidder is a man who has had absolutely no experience in doing the class of work bid upon.

The next bidder, higher by only the small sum of five hundred dollars, is experienced not only in this particular class of work, but in large engineering works of various kinds.

The private individual or a railroad company would very naturally reject the lowest bid and award the work to the next to lowest. In this case, unfortunately, the parties to make the award are the officers of a municipality, who are required by law to let the work to the lowest bidder, inasmuch as plans were on file and he is moreover financially responsible.

In our April number we presented an article on estimating which sets forth the great care which is exercised by the bridge manufacturing companies to obtain accurate estimates of quantities on which to base a cost. With all this care it is not possible for two estimators to arrive at results on the same piece of work which will agree much closer than two per cent, unless by accident. Suppose the lower estimate to have been made for an irresponsible concern and the higher for a concern of acknowledged standing, the cost of work per unit being the same for both, then we have the case in point repeated when they make bids upon the piece of work, one bid being two per cent lower than the other, although in *point of fact* they may be said to be identical. Manifestly, then, there should be some arrangement under the law by which the *real* low bid could be accepted.

In some States the law says the work shall be awarded to the lowest and *best* bidder. The officials often take advantage of this, even when plans are on file, and award work to others than the lowest bidder. Sometimes the bidders accept the decision, but too often for economy to the public, suit is brought by the lowest bidder, and, after expensive litigation, the work has to be readvertised.

The work under consideration was advertised three times before a responsible party was low bidder, and it could be awarded with safety.

The remedy could be found by amending the present laws or passing new ones which would declare all bids within a certain percentage, say two per cent, to be equal.

In lieu of this it is desirable to have complete plans prepared by competent engineers to place on file, making such requirements in the specifications as shall prevent the firms who are not competent from bidding, and at the same time not restrict competition from the better class of contractors.

The Soudan Bridge has been the subject of much comment by the daily press both in England and the United States, and the discussion has been taken up by the engineering press. As we understand the situation, the work was offered to English firms by the Egyptian War Office, but they could not promise delivery in

a short enough time. The bid of the American firm was so much lower and the time named for delivery so much shorter, that there was no recourse but to accept the tender.

As we have pointed out before, the mills and shops in this country are thoroughly up to date, while those of England, according to the say so of an American metallurgist who recently visited many of them, still cling to the manufacture of iron by the puddling process. The manufacture of steel in this country, where the metal never cools from the time it leaves the blast furnace until it is in the form of plates and shapes, is so much more rapid and less expensive, that there is really no comparison of methods. A prominent consulting engineer, who has built many of our modern furnace and steel plants, was recently called to England and paid a very large fee for advice as to the reconstruction of a large plant. Even with modern equipment, we doubt if English establishments will be able to compete with the best equipped American ones, owing to the very low price of our raw materials.

Again, with several firms in this country about the size of the one which received the Soudan order, supplying everything from the raw materials to the finished structure, is it to be wondered at that the element of time can be taken care of so satisfactorily?

That charges of corruption would be made, was to have been expected, as this is often the first cry from the defeated, but having been made against a department of the English war establishment, it was deplorable, as a more rigorous and upright organization is not to be found among the governmental machinery the world over.

That European countries must have serious competition from the United States in all lines of trade from now on is to be expected, and a more impassioned view must be taken by them when the results are not the most pleasing.

EARTHQUAKE-PROOF STRUCTURES.—The only structures in Japan which seem to be earthquake-proof are the pagodas which are erected before temples. There are many which are seven or eight hundred years old, and as solid as when first built. A pagoda is practically a framework of timbers which starts from a wide base and is in itself a substantial structure, but is rendered still more stable by a peculiar device. Inside the framework, and suspended from the other, is a long heavy beam of timber two feet thick or more. This hangs from one end, and so the other ends are bolted, at each of the four sides, and one more heavy timber, and, if the pagoda be very lofty, still more timbers are added to these. The whole forms an enormous pendulum which reaches within six inches of the ground. When the shock of an earthquake reaches the pagoda, the pendulum swings in unison and keeps the center of gravity always at the base of the framework. Consequently, the equilibrium of the pagoda is never disturbed, and this is the explanation of the great age of many of them, when from their height one would suppose them to be peculiarly susceptible to the effects of an earthquake.

Reviews and Reports.

[This department will be open to reviews of technical books pertaining to Bridges and Framed Structures as well as to reviews of the publications and reports of technical societies and schools. We shall be pleased to receive early reports of technical society meetings and abstracts of papers of especial interest to our readers.]

The Proceedings of the American Society of Civil Engineers for April, 1899, contains reports of the meetings on April 5th and April 19th, as well as the first two meetings of the Juniors, one on March 13th and the second on April 12th, at which there was a general discussion on the subject, "The Duties and Responsibilities of an Engineer Inspector."

The committees were appointed for the Thirty-first Annual Convention, to be held at the Stockton Hotel, Cape May, N. J., June 27 to 30, 1899, one from the Board of Direction and a local committee of arrangements.

The "Monthly List of Recent Engineering Articles of Interest" has been very greatly enlarged to cover forty-seven publications, domestic and foreign. The list is subdivided under the headings of Bridge, Electrical, Marine, Mechanical, Military, Mining, Municipal, Railroads, Sanitation, Structural, Water Supply, and Waterways. The title of each article is given, the name of the author, an index number of the journal, and the date of publication.

The advance publication of the paper on "Comparative Tests of Bituminous Steam Coals," by John W. Hill, M. Am. Soc. C. E., covers some fifty-nine pages. It is a report of a series of tests on the value of coals for the Board of Administration of Cincinnati, the object being to obtain a series of factors with which to multiply the bids received for coal, so that it can be determined which is really the most economical for steam purposes.

The paper on "The Artificial Preservation of Railroad Ties by the Use of Zinc Chloride," by W. W. Curtis, M. Am. Soc. C. E., is a very exhaustive one, of a length of fifty-three pages. "Ties in General" are first discussed, reference being made to many publications on the subject and to the statements and reports of various engineers. Then the Report of the American Society Committee for 1885 is reviewed, as well as the progress since 1885.

Descriptions are given of the Thilmany Process, which injected first sulphate of zinc or copper and then a second injection of chloride of barium, forming by chemical action sulphate of baryta in the pores of the ties; the zinc-gypsum process, which consisted of the injection of a solution of chloride of zinc and gypsum; the Wellhouse or zinc-tannin process, which consists of the injection of a zinc chloride solution containing a little glue and a second injection of a solution of tannin; and the application of various processes by the Santa Fé Railway, the Union Pacific Railway, the Chicago Tie Preserving Company, the Southern Pacific Railroad, and various foreign roads and works.

The cost of treatment concludes the paper. The evidence would indicate that a treated tie is superior to an untreated white oak tie, but if only of equal value, the treated tie in many locations would be the cheapest—where some other wood than oak is available for treatment. The actual cost for treatment ranges from six to twelve cents per tie.

The paper on "The Theory of Concrete," by George W. Rafter, is a résumé of the tests made by the author on New York State work in 1896, to determine the quantities of material used in making a cubic yard of concrete. "The author holds that an erroneous nomenclature has considerably obscured the theory and practice of concrete work, so much so that very few contractors and engineers have other than exceedingly general ideas as to the real theory of what is in effect a very simple matter, there being, indeed, very little necessary except to insure the filling of the voids in the aggregate material with mortar. In the author's opinion, therefore, the proper form of

expressing concrete relations is not by parts 1, 2, 5; 1, 3, 7, etc., but rather to express the volume of mortar as a percentage of the volume of stone, the percentage figure used being large enough to represent a little more than the voids in the stone after thorough ramming."

The proceedings of the Montana Society of Engineers contain a draft of House Bill No. 28, prepared under the auspices of the Society and introduced into the Legislature, "creating the office of State Engineer, defining his duties and regulating his compensation"; also a copy of House Bill No. 29, establishing a standard of measurement of water, defining the equivalent of a miner's inch, etc.

The Proceedings of the American Society of Civil Engineers for May contains a report of the meeting on May 3, at which the paper by John W. Hill, M. Am. Soc. C. E., on "Comparative Tests of Bituminous Steam Coals" was read, and discussed by William Kent and Henry C. Meyer, Jr. Also a report of the meeting on May 17th, at which the paper by W. W. Curtis, M. Am. Soc. C. E., on "The Artificial Preservation of Ties by the Use of Zinc Chloride" was read, and discussed by J. I. Boggs, Oscar Lowenson, H. S. Haines, and Edward P. North.

The announcements are made regarding the Thirty-first Annual Convention, to be held at Cape May, N. J., June 27th to 30th. Instead of the presentation of papers as heretofore, six subjects are announced for discussion, two of them being of especial interest to bridge engineers, viz., "Should the Use of the Method of Wheel Concentrations be Discontinued in Determining the Stresses in Railroad Bridges?" and "In view of Present Knowledge of the Effect of Repeated Applications of Load, Should Fatigue Formulas Be Used in Bridge Designs?" It is to be hoped that interesting discussions will be presented on these matters.

The "Monthly List of Recent Engineering Articles of Interest" has been greatly increased and now covers sixty-three standard publications. Four and one-half pages will be occupied with the list of articles.

The first paper in the "advance publications" is one by Chas. H. Haswell, M. Am. Soc. C. E., on a familiar subject—"Pile Driving Formulas: Their Construction and Factors of Safety." The formulas of Saunders, Rankine, Molesworth, Mason, Trautwine, Nystrom, Wellington, and McAlpine are presented and discussed, and then a new formula is submitted. We do not believe that there is room for another formula, inasmuch as the Wellington formula is so very simple and so very satisfactory of application and in results. Notes are appended on the tenacity of piles, friction of pine sheet piles in clay, the use of followers, brooming and sheet piling.

The second paper on "The Groined Arch as a Covering for Reservoirs and Sand Filters," by Leonard Metcalf, Asso. M. Am. Soc. C. E., is a presentation of the history of the groined arch and of formulas which have been developed for the volume of masonry in groined arch roof coverings. The method of computing the strength of groined arches is also discussed and an account is given of recent examples of this form of construction in the United States, at Ashland, Wis., Somersworth, N. H., Wellesley, Mass., and at Albany, N. Y.

The *Journal of the Association of Engineering Societies* for March, 1899, contains the following papers:

"The Efficiency of the Bicycle," by Robert H. Fernald.

"Experience in Sewer Construction," by L. M. Hastings.

"Maintenance of the System of Separate Sewers at Newton, Mass," by Stephen Childs.

Mr. Fernald describes the results of experiments at the Case School of Applied Science, Cleveland, O., to determine the effect of various conditions upon the efficiency of the machine. The several experiments, each represented by a diagram, include the following comparisons: Chain and chainless bicycles, bicycles of different grades, bicycles in good and in bad condition, the effects of oiling, of chain protection, of difference of gearing, and of inflation of the rear tire.

Mr. Hastings relates experience gained in the city of Cambridge, Mass., respecting the effect of the character and condition of the soil upon the size, character and cost of a sewer system.

In Cambridge the soils embraced in the system included, first, the hills and highest lands, largely of clay foundation; secondly, the plains and lower land, of sand or gravel, apparently of drift or glacial age; and third, marshy

lands and flats adjoining rivers. Naturally, the difficulties encountered were greatest in the lowest of these three soils, and least in the highest. Several illustrated examples of the methods of overcoming these difficulties are given, and the author discusses the proper construction of tide outlets.

In the discussion Messrs. Desmond Fitz-Gerald, Alexis H. French and others give interesting information from their experiences.

The opportunity for the construction of a sewerage system for Newton, Mass., arose when the Metropolitan Sewer Commission located a trunk sewer up the St. Charles River, giving the needed outlet through Boston's main drainage works to Boston Harbor at Moon Island.

The Newton works are constructed upon the separate system, only house sewage being provided for. A system of surface water drains emptying into the brooks or river is being built.

The system of underdrains and the methods of flushing and of ventilation are discussed in detail.

The paper is discussed at some length by Messrs. T. Howard Barnes, William Nelson and Bertram Brewer.

CURRENT LITERARY REVIEWS.

The leading article in *Appleton's Popular Science Monthly* for June contains an important announcement by Prof. G. F. Wright regarding a "New Method of Estimating the Age of Niagara Falls;" a problem which has given rise to much study and discussion among geologists, and about which very various views are still held. "The Abuse of Public Charity," by the Comptroller of New York city, is a surprisingly temperate and thoughtful arraignment, considering its source, of the present system of turning over city money to irresponsible charity organizations for use without any accounting to the taxpayers. "San Francisco of the North" is an article by Prof. Angelo Heilprin, giving an account of Dawson, the metropolis of the Klondike. A number of striking illustrations accompany the text. Dr. J. L. M. Curry, late minister to Spain and general agent of the Peabody and Slater Educational Funds, contributes an article on "The Negro Question," in which he insists upon the seriousness of the problem for this country, and points out some of the inherent difficulties which have prevented a better understanding between whites and blacks. A very timely article by J. Russell Smith, "The Philippine Islands and American Capital," points out some of the fallacies which have been urged by our politicians in exploiting the annexation to the United States of this group. "The Reptiles and Fishes of the West Indies," by Dr. F. L. Oswald, describes and pictures a number of the curious creatures which inhabit the newest of our possessions. Luigi Luccheni, the anarchist assassin of the Austrian Empress, is described by Cesare Lombroso, the great Italian criminologist. His origin, early history, and mental and physical qualities are taken up in detail, and finally the futility of simply executing such men is pointed out, and the true remedy shown to be an improvement in the social conditions of the lower classes and the peasantry, which in Italy to-day are immoral and squalid almost beyond belief. Prof. Pelham Edgar contributes an interesting essay entitled "Tendencies in French Literature," which is based on Prof. Bowden's "Recent History of French Literature." "The Botany of Shakespeare," by Thomas H. Macbride, calls attention to one of many interesting sides of the great bard's work, and points out, as typified by his references to botanical subjects, the marvelous faculty for close observation which he possessed. Dr. Marcus Benjamin contributes an instructive article on "American Industrial Exhibitions, their Purposes and Benefits." "Bookworms," metaphorical and literal, is the subject of an instructive as well as entertaining article by Willard Austen. A curious account of "Hydrophobia in Baja (Lower) California" is given by Dane Coolidge. In this, as in several other very hot and arid regions, rabies is common even among wild animals, and very much feared by the inhabitants, it being stated that whole ranches in some sections are rendered unusable by its prevalence. M. André Bracchi is the author of a study of "The Sense of Color." The "Sketch" this month is of Thomas Egleston, mineralogist and the founder of the Columbia University School of Mines. Titles in the Editor's Table are "Science and the Ideal" and "Racial Geography."

TRADE PUBLICATIONS RECEIVED.

"The Paint Wonder" is the title of a twelve-page folder issued by the Shearer-Peters Paint Co., of Cincinnati, in which is given something of the origin, composition and virtues of Pyro Paint, together with a long list of testimonials from users of it.

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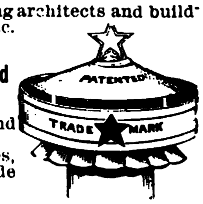

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Contents for July, 1899.

*Illustrated.

geological scale are found about Cincinnati, and belong to the Lower Silurian, corresponding to the Hudson River group of New York. These rocks in Ohio consist* of three similar blue limestones, "all highly fossiliferous." These three beds—the Point Pleasant, Cincinnati, and Lebanon—are found in outcrop in Warren, Clinton, Montgomery, Butler, Clermont, Hamilton, and Preble Counties, occupying the extreme southwestern portion of the State. All are used in a local way in and about Cincinnati and neighboring towns for bridge work, foundations, and lime, the latter being somewhat hydraulic. The stone is not of great commercial importance.

The Clinton Limestone—Above the Lower Silurian, the first of the Upper Silurian in Ohio is a red shale, corresponding, according to Dr. Orton, to the Medina Sandstone of New York. Over this shale, in a number of counties of Southwestern and Western Ohio, is a crystalline limestone suitable for

CHANNELERS IN QUARRY NO. 6, NORTH AMHERST, O. BEREA GRIT.

rubble rather than ashlar, owing to its irregular cleavage. It is usually quite pure, and is variously colored. This again is unimportant, except in a local way.

Dayton Limestone—But above the foregoing stratum is the Dayton stone, taking the same place in the scale as the Niagara shale of New York, and coming directly upon the Clinton. This is a quite pure, extremely compact crystalline limestone of great strength, a one-inch cube having shown a crushing strength of 21,500 pounds.* It is an excellent building stone, though not occurring in very thick beds. Cubical pyrite crystals are quite characteristic, but are not rapidly decomposed. The best known quarries are those of Dayton, Xenia, and Piqua. It is not widely known, though of good reputation where used.

Springfield Dolomite—Overlying the Niagara shales comes the Springfield stone (still in the Niagara series, and named from the city of Spring-

* Ohio Geol. Survey. Vol V.

* See Eng. News, Vol. 33. page 203. Stone X.

field, Ohio), occurring in several colors as a characteristic dolomite, porous and dull in fracture, and furnishing a first-class lime, and some very good building stone.

The Niagara is followed in the series by the Lower Helderberg, or water-lime formation, very similar to the Springfield dolomite, and also furnishing a first-class lime.

All the above named stones are found in Southwestern and Western Ohio, and their wide range leaves little territory in that region without its local supply of stone. But the more important formations of Ohio are higher up in the geological scale, both in the Devonian—so named from Devonshire, England, where a formation of the same age occurs—and in the Sub-Carboniferous which overlies it.

The Devonian Limestone—The Corniferous Limestone of the Devonian is found in a number of localities in Central and Northwestern Ohio, forming

THE KINNY ARCH, ELYRIA, O. BEREA GRIT.

a belt from Columbus to Lake Erie at Sandusky, Marblehead, and Kelly Island, and occurring as practically the only building stone of Northwestern Ohio at Whitehouse, on the Wabash Railroad, about twenty miles west of Toledo. It is not always a good building stone, and at Columbus it is treacherous, being better adapted to lime, or to use as a flux, than to building. It does not display itself well in the State House, and on the removal, about 1893 of the old tunnel under the tracks on North High Street, the stone used was found in a badly decomposed condition. However this may be characteristic of some portions only of the formation, and possibly, as is the case with many building stones, the objection may be removed by selection. The Columbus limestone is a quite pure, and, at some points, an extremely pure calcium carbonate. Toward the north it has a gradually increasing percentage of carbonate of magnesium, becoming, in the neighborhood of Sandusky, a magnesium limestone. The city of Sandusky is founded on the rock. In the fall of 1893, while there, the writer was shown a large

cellar which had been newly blasted out of the solid lime rock, and the stone so obtained used in the foundation walls. The face stone of the Sault Ste. Marie lock, finished in 1881, was from the Marblehead quarries, and the great lock, finished a year or two ago, which, I believe, is the largest in the world, is faced with stone from the same formation, quarried at Kelly Island. The Marblehead stone is also used in the Belle Isle bridge, 3,000 feet long, above Detroit, the total cost of the structure being $300,000. In many public works this rock has shown itself of good character. In the summer of 1897 the Kelly Island quarries were producing little beside coal-burned lime and rip-rap, though these were gotten out in quite a large way. Convenience to the lake makes transportation an easy matter. Our frontispiece shows one of the Kelly Island quarries in operation.

The Sub-Carboniferous furnishes the next building stones of importance

ENTRANCE TO QUARRY NO. 6, NORTH AMHERST, O. BEREA GRIT.

after the Devonian limestone. Here occur the Berea grit, the Waverly stone, and the Logan conglomerate, besides rocks of less importance.

Berea Grit—The well-known Berea grit furnishes one of the finest building stones in the country, and has been extensively employed. It occupies the second place above the Devonian shale, being underlain by the Bedford red shale of the Sub-Carboniferous. Its distribution in Ohio is wide, extending from Ashtabula County through Cuyahoga, Lorain, Huron, Crawford, Morrow, and Delaware Counties to Franklin. But the quarries of Amherst, Berea, and Grafton are perhaps most generally known. Two of our illustrations are views in Quarry No. 6, between North and South Amherst, in Lorain County, as it appeared in 1895. This excavation is something like half a mile long and 140 feet deep, nearly all the rock taken out being used in one way or another. There were at the time mentioned something like fourteen channelers and half a hundred drills in use.

This is only one of many quarries where stone of almost any commercial size may be obtained. A block about 25x2½x2½ feet was shipped to Mil-

waukee on Government work about 1893. This came from one of the Berea quarries in the Baldwin Flats. These latter quarries display a beautiful sight when the stone has been extracted over any considerable area at the same elevation, for the cleavage is so truly horizontal that a surface like a floor is presented. There are few sections of the country to which the Berea grit has not found its way either as grindstones, curbing, flagging, or building stone. It is a nearly pure homogeneous, siliceous sandstone, of a buff or gray color, according as it lies above or below permanent ground water.

Pyrite occurs to some extent. Crushing strength will average between 8,000 and 10,000 pounds. Properly selected, it is one of the most durable, though it is sometimes defaced by a white efflorescence, or has disintegrated on exposure. A case of the first kind is found in the north end of the High Street viaduct at Columbus, Ohio, and of the second in Cleveland, in the retaining wall at the foot of Lake View Park, on the lake front. Notwithstanding these instances, the pure siliceous character of the stone, its free

SHARP'S QUARRY, SUGAR GROVE, O. LOGAN CONGLOMERATE.

working qualities, and its general reputation for durability, have given it a deservedly enviable place among building stones.

Among the bridges in which the Berea stone has been used, the following may be mentioned:

The Kinny Arch (see illustration).

The L. S. & M. S. Railway arch bridge (which forms the initial illustration of this article).

The West bridge.* All the above at Elyria, Ohio.

The Wheeling arch,† in which about 9,000 cubic yards were used, the cost of the bridge being $103,000.

The Cherry Street bridge at Toledo, Ohio.

The L. S. & M. S. and C., R. I. & P. track elevation in Chicago, in each crossing of which one abutment furnished by the L. S. & M. S. Railway is

* Illustration—Stone, May, 1898.

† Described with illustration in Stone, Sept., 1898.

of Berea stone, while the other, furnished by the C., R. I. & P., is of Niagara limestone from below Chicago.

The following bridges in Cleveland, Ohio: Central viaduct, consisting of two parts, the Cuyahoga Valley and the Abbey Street, in which 16,800 cubic yards of Berea stone were used in the abutments, piers, and pedestals, the cost of the entire structure being $675,000.

The Superior Street viaduct, finished in 1878, in which 80,500 perches, or about 75,000 cubic yards, were used, mostly in ten nearly semicircular masonry arches, spans varying from 83 to 97½ feet in the clear, the structure alone costing $1,600,000.

The Columbus Street double swing bridge, in which 2,300 cubic yards were used, and, in fact, stone from this horizon has been used in nearly all the bridges of Cleveland and vicinity. The list of residences and buildings of all descriptions in which the Berea grit is used would be interminable.

QUARRY NO. 6, NORTH AMHERST, O. BEREA GRIT.

In Southern Ohio the same horizon furnishes the Lithopolis blue stone, the Waverly brown stone, the Buena Vista stone, etc., all fine grained, homogeneous, argillaceous free stones, which were formerly much more widely employed than now. Many of the quarries are convenient to the Ohio River for transportation.

The Logan Conglomerate—In the neighborhood of Lancaster and Sugar Grove, in Fairfield County, Ohio, and in various places along the Hocking Valley, is found a massive, rather coarse, and loosely cemented sandstone, sometimes containing a great many pebbles, and of a color varying from white through buff to red, according to the amount and character of the cement. This is the Logan, or Waverly conglomerate, at the top of the Sub-Carboniferous. It was used in the locks of the Hocking Canal, built more than half a century ago, one of which is seen among our illustrations. It is here cemented with an hydrated oxide of iron, which gives the stone its brown color.

QUARRY NO. 8, BEREA, O.

The ultimate strength is usually from 4,000 to 5,000 pounds per square inch. It has shown itself a very fair stone. It may be seen at the south end of the High Street viaduct at Columbus, Ohio, and also in the Fasset Street bridge (cost $200,000), across the Maumee at Toledo, Ohio, which latter bridge is shown in part in our illustration. We include also photograph of the quarry near Sugar Grove which furnished the stone for the last-named structure.

Carboniferous—The building stones of the Carboniferous are many, but are not usually of the first class. In the neighborhood of Killbuck, Holmes County, a ledge of excellent brown stone is found, cemented by the anhydrous oxide of iron. The stone is massive, rather coarse in texture, and of good color. It has been much used in Columbus, Ohio, as a building stone. Throughout the Southeastern part of Ohio the coal measure sandstones are common, and a few limestones occur. In the neighborhood of Bellaire a sandstone is found which has been used in and about Wheeling. The Market Street arch bridge, Youngstown, illustrated in the June number of BRIDGES, rests on a substructure of local coal-measure sandstone, in appearance much like the Sugar Grove stone of the Waverly conglomerate.

*The Indiana Building Stones**—Of the stones of Indiana, the Bedford Oölitic stone is far in the lead, and ranks well with the best of the country. Geologically, it is of the Sub-Carboniferous. Geographically, on the north the stone begins to be commercially important at Gosport, Owen County, extending thence southward and eastward through Monroe, Lawrence, Washington, and Harrison Counties. Quarries are located at or near Romona, Stinesville, Elletsville, Bloomington, Clear Creek, Bedford, Salem, Corydon, and at intermediate points. The stone is, as its name indicates, largely made up of fossils. It is an almost pure calcium carbonate, of a rather open and porous texture, and exceptionally free working. In color, as is the case with the Berea grit, it is classed as blue or buff, according to the degree of oxidation of the contained iron.

The crushing strength varies from 4,000 to 10,000 pounds per square inch, with 8,000 perhaps a fair average. As to durability, the Bedford Oölitic ranks well. Like every other stone, good as well as bad, it has some drawbacks, and it is said to exfoliate or scale at times. However, this objection may be removed by selection. The general use of the stone is shown by the fact that in 1897 Indiana produced oölitic stone to the value of $1,344,000, being the larger part of the stone production of the State.

It has been used very largely in bridge work. The following list has been adapted from the Twenty-First Annual Report of the Indiana Geological Survey.

Bridge over the Missouri at Bellefontaine Bluffs, Missouri, costing $1,500,000; built by Morison; 8,000 cubic yards.

Bridge over the Mississippi at Alton, Ill.; cost, $1,250,000; Morison, engineer; 10,000 cubic yards.

Bridge over the Ohio at Cincinnati; cost, $1,250,000; M. J. Beckir, engineer; 9,000 cubic yards.

Twenty-six city bridges over the Chicago River.

Metropolitan Elevated Railroad bridge over the Chicago River.

It has also been employed in many other structures throughout Indiana,

* For notes on Indiana Stones I am indebted largely to the Indiana Geol. Survey—Portions by Messrs. Hopkins and Siebenthal.

HOOSIER QUARRY A, BEDFORD, IND. (OLD VIEW.)

Illinois, and Missouri, including several of large size. In building work, it is now the favorite in New York city. Transportation is well provided for. The Monon passes through the entire length of the quarry region, while the Indianapolis and Vincennes Division of the Pennsylvania crosses it in Owen County, opening up the Romona district. The B. & O. Southwestern also crosses the oölitic belt in Lawrence County. The Bedford Belt Railway "has contributed in no little degree to the development of the stone interests of Lawrence County."

Mansfield Sandstone—Indiana building stones are not limited to one horizon, or to one or two localities, but we will confine ourselves to noting one more building stone of value for bridge work—The Mansfield standstone of Western Indiana. It is named from Mansfield, Parke County, and is found in outcrop in Warren, Fountain, Montgomery, Parke, Putnam, Clay,

ON THE HOCKING CANAL. LOGAN CONGLOMERATE.

Owen, Greene, Martin, Orange, Crawford, Dubois, and Perry Counties.*

The description of the Waverly or Logan conglomerate of Ohio applies well to the Mansfield. They are of the same geological period, and must have been formed under similar conditions. Both have more or less of the conglomerate character, but not sufficient to make the name applicable to the whole formation. Stone from this horizon has been used for many years for local bridges and "along the Wabash Railway in Warren and Franklin Counties, built in 1856, Mansfield stone was used in some of the bridges and culverts, and was found to stand so well that in most of the new culverts constructed during the last few years the Mansfield stone has been used." It has also been used along the line of the C. & E. I., and in at least one bridge in Chicago.

As will be seen in the table at the beginning of this article, Illinois ranks high in the production of stone for building purposes, the greater part of which is limestone from Will and Cook Counties. This is found at Lemont, Lockport, Joliet, and intermediate points, as well as within the limits of

* 20 Annual Report Indiana Geol. Survey.

Chicago. It is of the Niagara, and a true dolomite. The Chicago drainage canal for a considerable portion of its length is cut through the formation, and the immense ridge of lime rock lying along the bank of the canal below Lemont will indicate the possibilities as regards supply. On top it occurs in thin layers, and is practically useless, but increases in thickness and value downward. In 1894 the production of limestone in Illinois was valued at $2,556,000. But in spite of the importance of the industry, the State has never had a thorough geological survey, owing to an unfortunate lack of appropriations for such purposes. Professor Rolfe says: "I do not hesitate to say that a survey would develop an abundance of excellent material for this grade [bridge stones] from the outcrop of the Trenton, Niagara, and Sub-Carboniferous, that are now unknown." Limestone of the Sub-Carboniferous is quarried at several points along the Mississippi in quite a large way. The production of sandstone is small.

FASSETT STREET BRIDGE, TOLEDO, O. LOGAN CONGLOMERATE.

Wisconsin—The building stones of Wisconsin are now coming into prominence, at least in their own State. The Wisconsin limestone, a dolomite of the Niagara, has been used in the bridges of Milwaukee, and is favorably reported. Sandstone is quarried in a small way, mostly in the northwestern counties. Some granite is produced in the northeastern and central portions of the State. With proper development, Wisconsin will take a good place in building stone production.

Michigan—Most of the Michigan limestone is used in making lime, but the backing-stone of the great lock at the Soo is a limestone from Lime Island, Chippewa County. The Lake Superior sandstone is coming into use quite generally, especially in fine building work.

Kentucky—The output of stone for building purposes is not large, cement production being of the greatest importance.

In closing, it will be noted that the building stones of several of the Central States are only awaiting a fuller and more general exploitation to bring them into prominence.

C. A. RAYMOND.

THE ERECTION OF LARGE PLATE GIRDER SPANS.

THERE has been in the last few years a steady encroachment of the plate girder upon the territory once held exclusively by the lattice girder, or pin-connected truss. The possibility of obtaining angles and plates in much longer lengths than formerly is largely responsible for this. A girder span of 85 feet, shipped in one length, was until a few years ago considered an achievement of sufficient moment to receive mention in the engineering papers. If a girder span of this length was used, it was probably made in two or three sections and riveted together in the field. To-day girders of 105 to 115 feet in length, riveted up complete and shipped in one length, are common at any of the larger shops. This is not as unusual, in fact, as the employment of a pin-connected truss to span an opening of this length.

Plate girders, where carrying railroad or city traffic across openings of such lengths, become so heavy as to require special appliances for their handling and transportation. The up-to-date erection department must be prepared to handle quickly and safely weights of thirty to forty tons. The limit is reached only when the length and weight become such that the railroads can no longer handle them with safety at their bridges, tunnels, and curves.

Much time and thought have been spent in considering the question of the safe transportation of these huge masses of steel. They must be securely braced, and at the same time allow perfect freedom for the cars to adapt themselves to curves. The center of gravity must not shift greatly, and the ends must not project far enough to be in danger of striking bridges or obstacles near the track. Figures 1 to 4 show methods of loading and bracing. The girders are usually loaded in a vertical position upon two or three cars. When loaded upon three cars, the center one is an idler, carrying no portion of the load. The photograph, Fig. 5, shows a large girder loaded on three cars; the bolsters under the girders, and which rest on the two end cars, are pivoted on steel pins.

If possible, the girders should be so loaded on the cars that it will not be necessary to turn them end for end in the field. If the bridge is at a new location, one of the following methods may be used: First—Bents of falsework are erected at intervals across the opening, and a temporary track laid upon them. The girders are loaded upon trucks and run out upon the falsework, where derricks or gin-poles pick them up and lower them into position. Second—One or more derricks may be set up near one abutment, and the girders picked up by these and swung into their position on the masonry. In this case, no bents of falsework are used. If there are floorbeams between the girders, it may be necessary to set the girders slightly farther apart than their final position, until the beams are put in, to allow these to be swung into position. The girders are then slid into position, and the beams and bracing riveted up.

If the new bridge is over a railroad, the girders might be run out on this

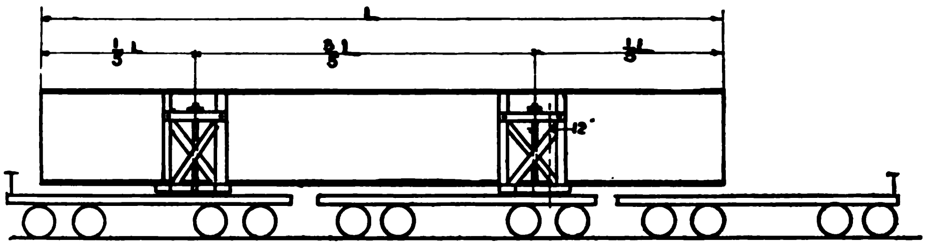


FIG 1.

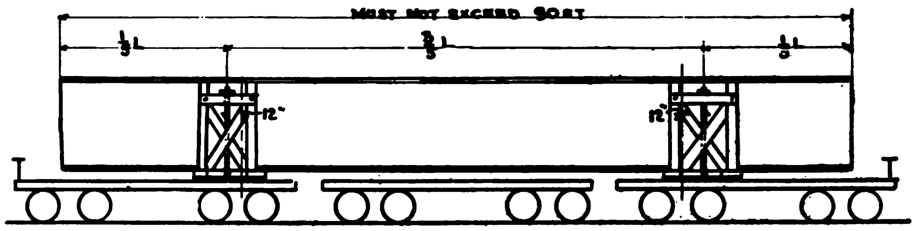


FIG 2.

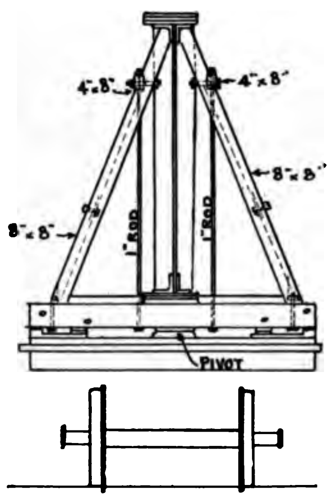


FIG 3.

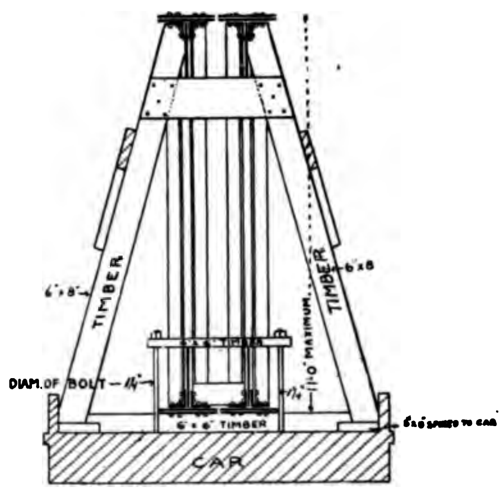


FIG 4.

track and picked up and swung into position either by a derrick or bent at each end, or by one bent or pole near the center. Figs. 6 to 8 show girders being raised by single bents near the center of the span.

The girders at Thirteenth street, Philadelphia, were taken from the cars on which they were shipped from the shop, and swung into their position on the masonry by one derrick set up near one abutment. The huge girders at Willis avenue, New York city, were raised by one steel traveling derrick which ran on a track laid upon the adjoining span. These girders weighed about thirty-one tons each.

Fig. 9 shows a portion of the Wheeling, W. Va., bridge. Here the girders were run out on a temporary track laid on the falsework stringers.

FIG. 5.—METHOD OF LOADING GIRDERS ON CARS.

The two "A" travelers, which also run on tracks laid near the outer edges of the falsework, pick up the girders and swing them into place.

Where the new bridge replaces an old structure, the method of procedure is somewhat different. Traffic must be maintained without interruption, and the track kept in a safe condition at all times. The plan usually followed is to run the girders out onto the old bridge, still loaded upon the cars on which they were shipped. By means of derricks, gin-poles, or bents, they are then lowered down beside the old bridge until they rest on the masonry or on temporary bents erected for the purpose. When there is an interval of several hours between trains, the old span is lifted

out and the new girders moved into position, the bracing put in, and the floor laid sufficiently to allow the next train to pass. The riveting and remaining work can then be done at leisure.

Fig. 10 shows a girder being raised from the cars and lowered down into

SKETCH SHOWING METHOD OF HANDLING GIRDERS WITH BENTS

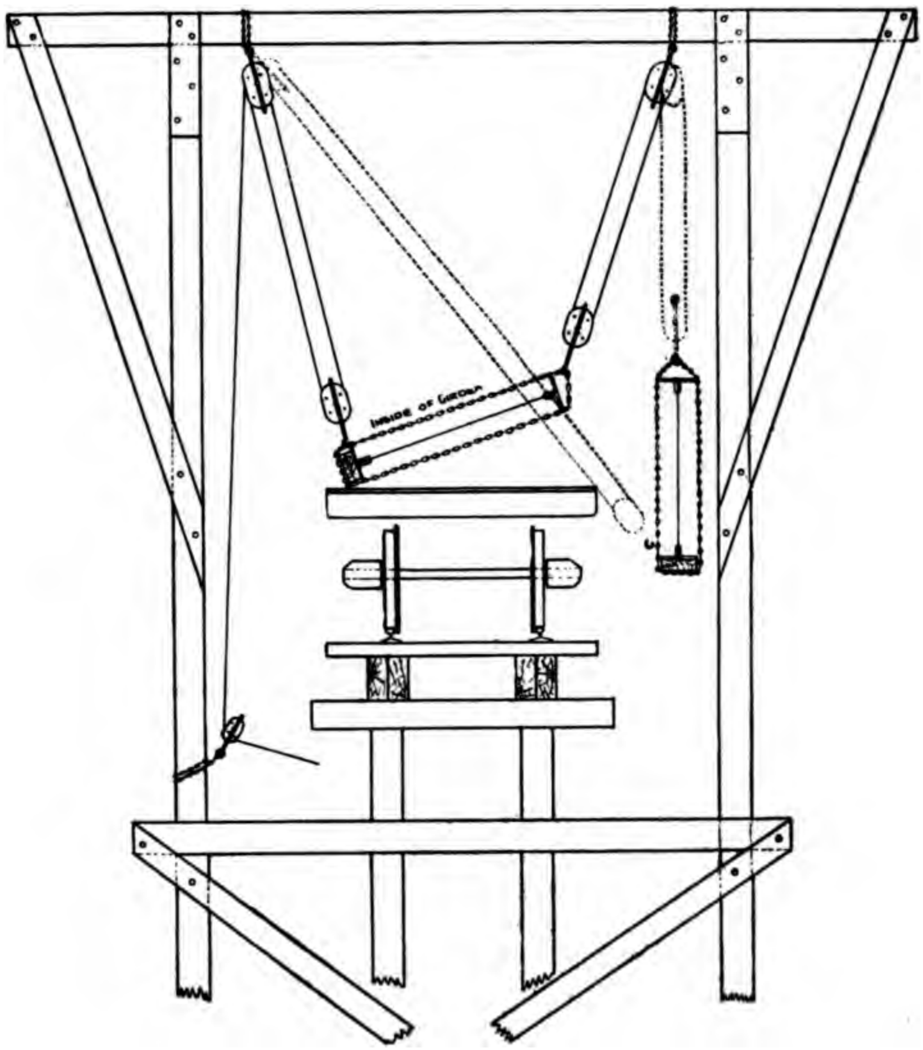


FIG. 6.

position. There are two lines attached to the girder at each end. One of these is slacked off when the girder has been lifted clear of the car, and hangs vertically. This line prevents the girder swinging out and striking the bent as it is lifted clear of the car.

Where the time between trains is very limited, the new span is often

erected on falsework by the side of the old span, the riveting finished, and the floor and rails laid complete. The old span is jacked up and placed on rollers or on smooth rails well greased. These rails or rollers also extend

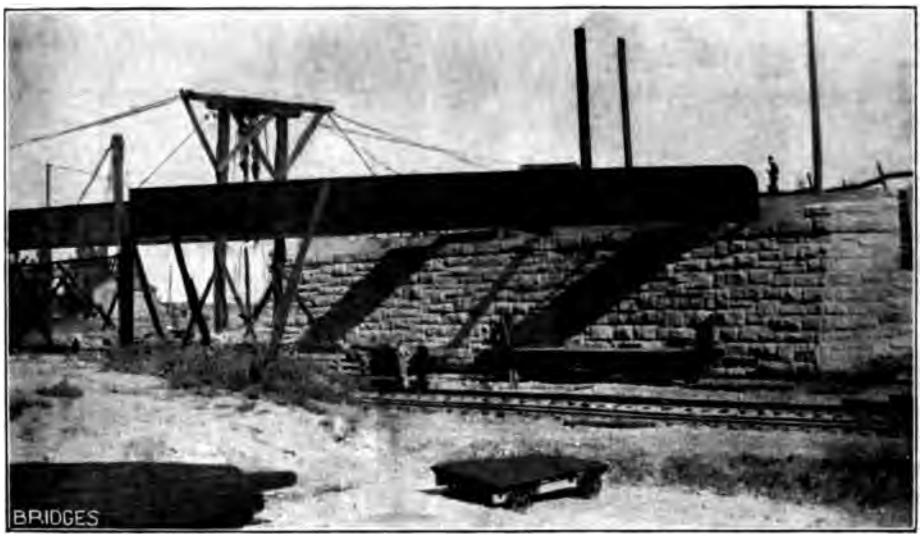


FIG. 7.

FIG. 8.

under the new span, and far enough on the opposite side of the old one to allow it to be moved out of the way of the new span when in its final position. When everything is ready and there is an interval between trains, the old span is rolled out sideways and the new one rolled in, the rails connected

up, and trains can then pass over the new structure. The rails and rollers are taken out at convenience and the span let down onto its permanent bed-plates. The shifting of the spans is done by ropes attached to loco-

FIG. 9.—PLATE GIRDER BRIDGE OVER WHEELING CREEK.

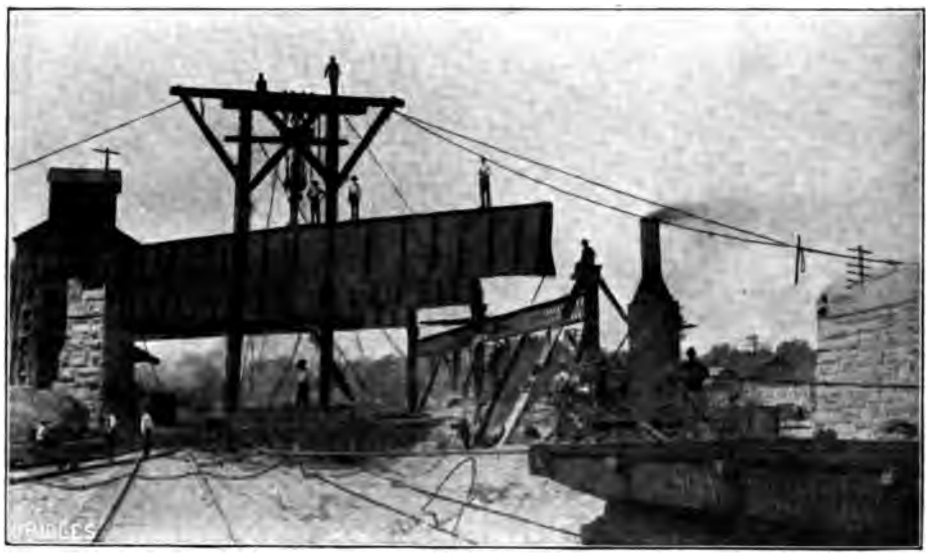


FIG. 10.—GIRDER BEING RAISED AND LOWERED INTO POSITION.

motives or to hoisting engines, and is often accomplished in ten or fifteen minutes. In one instance, at least, it has been done in much less time. To lighten the old structure, the rails may be pulled off by attaching a rope to

FIG. 11.—GIRDER FALSE WORK AND TRAVELER ON B. & O. S W. R. R.

FIG. 12.—GIRDER ERECTION ON THE C. A. & C. R. R.

them and to a locomotive, removing both lines at once from the entire length of the span. The ties are sometimes removed also. A line is fastened securely at one end of the span, passed under the ties and then back on top to the same end of the bridge. The line is made fast to a locomotive, which is then started, and the ties are bunched up and pulled off the bridge in a manner similar to the rolling up of a window shade.

Fig. 11 is a photograph showing the falsework and traveler used in the erection of a 103-foot girder on the B. & O. S. W. R. R. at Chillicothe, Ohio. The traveler had been previously used to take down an old through span.

The Engineering News of March 5, 1896, gives a description of the erection of two 91-foot girders on the C., A. &. C. R. R., from which the following brief extract is taken:

"The girders were 9 feet deep, and were carried on steel columns, the height being about 50 feet above the stream. The spans were riveted up complete in the shop, so as to utilize the short time between trains to place an entire span. The columns having been put in place, the cars carrying a span were shifted out on the old bridge, the girders lifted up by the gallows-frames to allow the cars to be pulled out of the way, and then the track and old ties were removed, so that the span could be lowered down between the old trusses, as shown in the view. The new ties and track were then laid, and trains allowed to pass, after which the old trusses were removed at leisure."

In the Record of April 29, 1899, there is a description of the erection of the bridge at East Brookfield, Mass., on the B. & A. R. R. This bridge was erected alongside of the old span, and then the old span slid to one side and the new one moved to its place.

The writer is indebted to Mr. H. F. Lofland, Engineer of Erection of the Edge Moor Bridge Works, for a portion of the drawings and photographs shown.

CHAS. H. WRIGHT,
M. Am. Soc. C. E.

CO-RELATION OF THE CONTRACT TO THE SPECIFICATION.

II.

SPECIFICATION Against Engineer's Decision and Instruction—Usually the contract provides "that work, labor, and materials shall be done and furnished strictly pursuant to, and in conformity with, the specifications and plans and the directions of the engineer, as given from time to time during the progress of the work;" or, "in accordance with the detail drawings and directions given from time to time by the engineer;" or it is provided "that the work and materials shall conform strictly to the specifications and plans, and the whole shall be completed to the acceptance and satisfaction of the engineer." Sometimes (but not often) the engineer or architect has been known to ignore the specifications and plans, and to establish his personal standard of excellence with which the work shall conform, and the question is: Which shall prevail, the specifications or the engineer?

The answer is to be found in the contract, and is determined when the *intention* of the parties is ascertained. The engineer's powers and duties are limited to those which the contract expressly confers or may be clearly implied from its terms; he cannot go beyond nor behind it. His decisions relate exclusively to matters embraced within the agreement to submit to his directions and determination. He cannot alter the express provisions of the contract, nor add to its requirements. His decisions are conclusive only with regard to work described in the contract and specifications. The engineer must measure and classify the work and materials according to the rules and tests named by the parties. Even though he be sole judge of the work, its quality and character, he cannot accept what the contract forbids, nor demand what the contract does not require. He is confined to the acceptance of things which meet the requirements of the specifications, and the work or materials may not be accepted because they are as good or as suitable for the purpose, without the consent or acquiescence of the parties themselves. Neither the owner nor the contractor will be bound by the acceptance of the engineer unless the work and materials conform to the contract requirements, even if accepted in good faith or under an erroneous view of the contract. So far as the contract and specifications show an evident intention to limit the engineer's discretion and to fix or name the quality of the work, so far must he follow the specifications.

Loose and solid rock must be classified as such if it conforms to the materials described as such in the specifications. No intermediate classifications can be made. If the contract prices be 35 cents for earth and 75 cents for rock excavation, a price of 50 cents cannot be allowed for loose rock or hard pan. An extra price cannot be allowed by the engineer to relieve from hardships, as for picking or blasting difficult or frozen excavations.

The first duty of an engineer is to require that the work conform to the

specifications. That done, he may then exercise his discretion and good judgment. He may not accept a brick house for one of marble, even though the brick house is substantially as good, or even better, than the one of marble. He cannot accept blue stone for brown stone, nor a 12-inch wall for a 16-inch wall, nor Bessemer steel for open-hearth steel. When it is specified that mortar shall consist of equal parts of cement and sand, a different mixture cannot be authorized by the engineer. If it were not so held, mud might be accepted for good cement mortar.

An extraordinary case was recently reported, where a contractor was to build a sewer according to plans, profiles, and specifications, and according to the directions of the city engineer; by direction of an assistant in charge, the contractor laid part of the sewer at a less depth than shown on the profile and required by the specifications. Later a new assistant, having been assigned to the work, he required the sewer to be taken up and rebuilt at grade. The court refused the contractor any recovery for the extra work, and held that the engineer had no right to vary the plans and specifications. An engineer or inspector has no authority to permit deviations or changes in plans, unless it is expressly conferred.

When work and materials are required to be strictly according to specifications and the engineer is to finally accept and approve the work, and the contractor has completed the structure strictly in accordance with the plans and specifications, must the engineer accept and approve? In this as in all cases of conflict, it remains a question of *intention*. To determine that, the court should consider not only every part of the contract, but it will put itself in the shoes of the parties and consider the relations of the parties and the conditions and circumstances under which the contract was made. The court will consider the interpretation which the parties themselves have adopted. Generally when work is to be completed according to the specifications and to the acceptance and satisfaction of the engineer, and the specifications describe the work and materials in detail, it is sufficient to complete the work as specified. Such a performance should be to the *reasonable* satisfaction and acceptance of the engineer. This is sometimes so held, but the courts have sometimes held that the requirements that the work should be to the acceptance and satisfaction of the engineer was an additional safeguard. When the engineer has signified his acceptance and approval it will bind the owner even though there has not been a literal compliance with the specification; the engineer must act in good faith and if work has been completed according to the specifications and plans and the engineer refuses to accept and approve it, it is, at least evidence of, bad faith.

If the working drawings furnished by the engineer differ from the plans and specifications in material respects and the contractor has agreed to perform the work according to such detail drawings and directions, he can be required to do so and without extra expense. It is submitted, however, that the working drawings must conform reasonably with the original plans and specifications.

Materials that conform to specifications rejected by engineer and inspectors: All builders have had in their experience cases where materials have been furnished and supplied which, in their opinion, have conformed strictly with the specifications, but which materials have been rejected by inspectors or engineers. The question has arisen, how far the contracts and specifica-

tions will control and to what extent the power of the engineer in rejecting or accepting materials will bind the employer or company. If the engineer has been given the full power of an arbitrator or umpire, and his decision is made final and conclusive upon the parties, it is pretty well settled in England and in many of the states of the United States that his decision will control and that materials accepted by him must be paid for even though they prove inferior or defective. A contractor should secure the engineer's or architect's acceptance of materials before using the same, or he uses them at his peril. If materials are rejected, the engineer must be specific in describing the defects, and so explicit that the contractor can remedy them. A notice to a contractor that certain parts of his structure are "worthless and dangerous, not fit for use, liable to cause damage, and their construction in direct violation of the contract," without other specifications of the nature of the alleged defects, has been held insufficient to require the contractor to replace such parts or to defeat his right to a recovery.

When a certain kind of stone was specified and was used upon the works, and it was afterward found defective, the contractor was allowed to recover the contract price, it not being shown that the defect was in the workmanship. The same has been held of sand used which was particularly described and designated.

If the contractor gave notice of the poor quality of the materials, and the work is carried on under the eyes of the owner, he may not refuse to pay for the work because the structure is so affected by the weather as to prove worthless. The use of brick made of inferior clay in good faith by the contractor, the defective condition of the brick not being discovered by careful inspection, but developing only after exposure to the weather, will not defeat the contractor's right to recover. When the owner specifies certain brands of materials or a manufactured product, and arbitrarily confines the contractor to such materials, he takes the responsibility of any inherent defects which may develop subsequently and which are not discovered upon ordinary inspection.

In an English case where an engineer was to inspect, test, and approve of the work, and it was provided also that his approval should not relieve the contractor from the conditions and stipulations contained in the specifications as to the materials, work and test, and the engineer had power to reject materials on any ground whatever, and his decision on all points of doubt or dispute were final and binding on the parties, and it was further provided that the engineer should not in any way commit the company to the approval and acceptance of the materials which were not in strict accordance with the specifications and plans, yet it was held that after delivery, acceptance and payment for half of the materials, they were found defective, that the acceptance of the engineer was conclusive.

If inspectors are clothed with authority usually conferred, and the structure has been accepted and the contract fully executed and no fraud has been practiced by the contractor, it seems pretty well settled that the owner or company can have no recovery against the contractor for defective work or materials. Therefore when a contract required excavations to be made for a structure under the instruction of an architect and work is required by the architect and to his approval, it is performed, whether it be in conformity to the drawings made or not. So when the machinery for a steamboat was

required to be of the best material throughout, and of first-class workmanship, and the steamboat company was to furnish a suitable and competent person to superintend the construction with a right to reject anything not equal to the requirements of the contract, and to inspect the work, and every facility was afforded him to inspect the work and materials, it was held that the company could not recover from the contractor for injuries received if the steamboat failed. So too, when under a contract to construct a wharf according to plans and specifications furnished by the company to the contractor, and the work has been accepted after the company has seen it in progress and completed, no recovery can be had from the contractor because the structure proves defective and injury results. And when county commissioners had a superintendent who exercised the duties of an inspector and superintendent who was present during the erection of a bridge and who passed upon the work during its progress, and the bridge was erected and completed pursuant to his directions and in substantial compliance with the plans, it was held that the commissioners waived their rights to pass on the workmanship and materials, and their right to condemn either, unless there was collusion between the contractor and superintendent.

If the determination of the architect or inspectors be not made binding on the parties, it has been held that his acceptance of inferior materials will not bind the owner nor relieve the contractor from performing his agreement in strict compliance with the contract. If the work has not been accepted, the payment of progress certificates will not constitute a waiver of defects in quality which were not apparent from inspection.

If the contractor be subject to the direction of the engineer in charge, and the quality of materials furnished and the manner of doing the work are specified, he is not responsible for defects of the work as a whole, if he has complied with the engineer's directions.

The effect of the engineer's or architect's failure to object when work does not conform to the contracts and specifications, does not show acquiescence in such work as in the use of parts or members of a structure which are smaller or of different dimensions than those specified in the contract or in the placing of them improperly.

When it is provided that the materials shall be strictly in accordance with the plans and specifications, and that a person appointed shall inspect and accept such materials as he may deem proper, it was held that a difference of opinion between the contractor and inspector as to whether or not the materials conformed to the plans and specifications was an incident contemplated by the terms of the contract, and that the rejection of material in good faith by the inspector gave no grounds for damages to the contractor, even if the rejected materials did conform to the specifications.

When a structure is to be built according to specifications and to the satisfaction of the engineer, it may be doubted if his acceptance will hold unless the work has been done according to the contract. Stipulation granting such powers must be read along with the rest of the contract, and they must be exercised in accordance with the specifications and terms agreed to by the parties. Much *must* be left to the engineer's discretion and judgment which is for his own honest determination, but so far as the contract and specifications show an evident intention to limit the engineer's discretion and to fix the quality of the work and the degree of its perfect execution, so

far must the engineer follow the specifications and instructions. His duty is first to determine the conformity of things with the specifications and requirements of the contract, and as to the rest, consult his own discretion and good judgment. He must decide whether work has been executed in a manner and to a degree of perfection, promised or demanded in the contract. He cannot dispense with the performance of a substantial part of the work; he may decide whether work has been executed in a workmanlike manner, if materials are of the kind required, but it cannot be contended that the engineer can accept something totally unlike that which is called for, even though it is substantially built and for all practical purposes as good or even better than the structure specified in the contract. However conclusive the engineer's decision may have been made or however closely the contractor is to follow his instructions in all things, that will not justify a departure from the express terms of the contract. An acceptance by the engineer of a different class of work or of inferior materials will not bind the owner nor will it relieve the contractor from his agreement to perform according to plans and specifications.

Conflict between the specifications and plans and the judgment of the contractor as to how work should be done:—It frequently happens that contractors are made responsible for the maintenance and repair of work and are also required to do it according to specifications and plans, and the question arises as to which shall control. Here, as in many other cases, it is a question of intention. The courts look to the construction of the instruments to determine the intent. The question is, does the contractor guarantee that the specifications and plans are sufficient to effect such a result as he will be able and willing to maintain for the period named? As an instance, suppose that a contractor undertakes to build a structure according to certain plans and specifications, as a bridge, and according to the specifications and plans and directions of the engineer, and the engineer directs what kind of foundations shall be built, under the protests of the contractor that the said foundations are insufficient and will not support the structure. Nevertheless if the foundations are built according to the orders of the engineer, and the structure falls, is the contractor liable to reconstruct the foundations and the structure, or will the owner be required to pay for the work done in manner required? In determining this question, the courts have frequently decided it upon the ground that the contractor was to build and furnish a completed structure, distinguishing such cases from an agreement to do work at a unit measure or those where the different kinds of work were parceled out to several different contractors. The cases usually hold that if the contractor is to furnish a completed structure, then he is liable to complete and deliver over such a completed structure, and that by agreeing to furnish a completed structure, and to be responsible for the maintenance and repair of the work for a definite period, he has adopted and approved the plans and specifications by which the work is to be performed. This brings up again the subject of liability for work whose failure is due to defective plans, and what has already been said upon that subject will apply with equal force here.

Conflict of specifications with work and materials furnished by other contractors: Specifications for work are sometimes not fully and completely performed in regard to work done by other contractors, the defective con-

dition of which a post-contractor may be required to make good. The economy and quality of a painter's work often depends upon the work done by a carpenter, and the masonry work often depends upon the stone-cutter's work, and the successful and satisfactory completion of almost every kind of work depends in a degree upon the skillful performance of work by other contractors or material men. It is frequently a question in doing mason work as to who shall furnish the centers for the arches, whether the mason or the carpenter should supply them. Usually the obligations of each contractor is an obligation to the owner of the structure, and there are no relations between the several contractors except such as are created in the contract. It therefore follows that one contractor is under no obligations to another contractor; his obligation lies to the owner. If, therefore, a contractor has any remedy when work which he takes up is defective, his only remedy is against the owner, and it therefore becomes the obligation of the owner to enforce contract obligations against each and every contractor. If the owner does not enforce such obligations and require that each contractor do his work skillfully and completely, then he should be held liable to other contractors for any injuries or damages which the latter may suffer.

In connection with this same question there are cases where the owner himself is to furnish the materials for a certain part of the work. If the owner is to furnish the materials, as the iron and steel for a frame structure, and the contractor is to forge and assemble such materials into a complete structure, and the materials do not apply in every particular with the specifications, the question arises whether the contractor is liable for the failure of the structure in consequence of the poor and defective materials furnished by the owner, and if the contractor has not waived his rights by failing to protest against the use of such materials.

Specifications and satisfaction of owner:—When work is to be completed to the satisfaction of the owner or employer, and specifications have also been prepared, or a certain *result* is to be obtained which has been defined and described, and the work has been completed according to such specifications, or in such manner as to accomplish a certain definite result, the question arises if the owner *must* be satisfied. If the contractor has undertaken to do the work to the full satisfaction of the employer, he cannot be considered to have fulfilled his contract obligations until he has completed the work to the satisfaction of the employer. If the structure to be erected is one that cannot be removed and is a benefit to the owner or employer, it is unreasonable and unjust that the contractor should be denied a recovery for the reasonable value of his work and materials, or at least for such an amount as the owner or employer has been benefited. The courts are therefore in sympathy with a recovery to the contractor in such cases. The cases of work upon chattels and manufactured articles is distinguished from that of work upon buildings or structures. In the former case, the courts maintain that the contractor can virtually be placed in *statu quo* by the return of the chattel or manufactured article which does not suit the employer, and therefore the courts usually hold that no recovery can be had. But when the work has been the erection of a bridge or a piece of machinery or a house, which, by virtue of its permanent character has become attached to the land of the owner, the courts hold that if the work has been done according to the plans and specifications prepared and submitted by the owner, that it should be

and must be to his satisfaction, and that therefore he must recompense the contractor. The courts hold in such cases that work need be completed only to the owner's *reasonable* satisfaction.

When, therefore, a contractor was to receive for a public work "whatever recompense the Board might allow as right and proper," it was held that the contractor could sue for a reasonable compensation, even though the Board had tendered him what it considered right and proper; and when an employee who was to be paid whatever he saw fit to charge, it was held he could not make his charges unreasonable.

The dissatisfaction of the owner must be in good faith, and he can take into consideration only the performance of the conditions of the contract. He may not consider the structure in respect to materials not contracted for, and the right of approval must be exercised in a reasonable manner and not arbitrarily nor capriciously for the purpose of defeating the contract.

Effect of plans and specifications on the status of an independent contractor:—The plans and specifications should contain all those instructions and directions that shall be necessary to secure the *result* sought. They should be so complete that they shall require nothing from the engineer or architect but a technical interpretation and explanation, which cannot reasonably receive but one interpretation at the hands of a conscientious engineer. If the specifications be not complete and do not embody such directions and control as shall fix and determine fully what the contractor is to do and how it is to be done, and the owner or his agents (engineer or architect) is required to assume direction and control of the contractor and his employés, then the contractor ceases to be an independent contractor, and he and his help become the servants of the owner, who is responsible for their acts or negligence. Such relations of the parties is to be avoided, as it is one of the principal objects in letting work to contractors, to avoid the responsibility due to the acts and negligence of the contractor and his servants. It is a well-established principle of law that the owner cannot reserve the control and direction of the contractor without assuming the responsibility for his acts. It is therefore recommended that the contract shall not give such powers of direction and control to the engineer, but that the specifications and plans shall so clearly and explicitly define what is required of the contractor that the engineer or architect shall only have to define and interpret such specifications and plans without assuming control. To accomplish this, the engineer is usually given the general supervision and explanation of the plans and specifications, and then only where there are apparent omissions or conflict between the several parts of the specifications itself or between the specifications or the plans and the contract.

Application of specifications to extra work:—A provision that is often omitted in contracts, and which is of considerable importance at times, is one to require that extra work or "extras" shall conform to the specifications and plans. Extra work, strictly, is work outside of and not included in the contract. Clauses which provide for the engineer's determination and acceptance in regard to materials and work done under the contract, have been frequently and generally held not to apply to extra work. If such clauses and stipulations of a contract do not apply to "extras," then it may well be doubted if the specifications and plans would have application to work done outside of the contract, any more than do other phrases and clauses of the

contract. This question is rarely raised because it is probably a foregone conclusion among contractors and engineers that it was and is, the intention of the parties to have the materials employed in extra work conform to that work which is expressly provided for in the contract. The manifest intention of the parties is to have good, substantial work done and to employ materials of good quality and make, and in order that the job or structure should conform throughout to good workmanship, it is a natural inference that the specifications should be followed in providing and furnishing extra materials and work, as for the work specially provided for; but this conclusion is perhaps no stronger than that it was intended that the engineer should determine questions in regard to extra work as well as questions in regard to regular work.

Whether a contractor would be excused for the defective condition of extra work when he has done it according to specifications, would depend upon the circumstances of each case. Without doubt the general presumption, that an undertaking to furnish materials and to do work requires the contractor to furnish such materials and work as shall accomplish the purpose for which it was intended, applies as well to extra work undertaken, as it does to general work. Therefore when in the construction of a house, a contractor is asked to build the foundation and walls of a cistern, and he uses the same proportions of cement, sand and stone for concrete as was used in the foundations of the building, it was held that he was liable for the defective and leaky condition of the cistern and could not excuse his failure to make it tight by explaining that he had followed the contracts and specifications in the making of the concrete. If, however, the work had been done under the eyes of inspectors and the architect, and with their approval, it is very doubtful if the contractor would be held liable for the defective condition of the work.

In this discussion of the relation of the contract to the specifications, enough has been said to show that in all cases of conflict, it is a question of *intention* of the parties, which is to be determined by the court, after a due and proper consideration of all the terms of the contract and the circumstances surrounding the parties at the time they entered into the contract. The intention ascertained, it will prevail in all cases.

A matter that has received much consideration and has been a topic of much discussion in engineering and architectural circles, is the relative length of the contract and specifications. The subject is really one of little importance, and should be determined by the universal rule, that all legal documents should be made as brief and clear as is possible. The length of the contract or specifications will be determined solely and entirely by the detail and care with which the parties and their engineer define their intention, and that will in turn be determined largely by their ability to use good, pure English. The intention should first be determined and it should then be clearly and plainly expressed. That alone will determine the relative length of the contract and specifications. If the engineer be painstaking, conscientious, and one in the habit of going into great detail, the specifications will be prepared at great length, and if the lawyer who prepares the contract be concise and confident of his success as a trial lawyer, the make-up of his character will be reflected in the contract, and it will be proportionately abbreviated. No suggestions or set rules can be suggested in regard to such

matters; it depends largely upon the personal equation and the experience of the party who is preparing them.

As to what the intention of the parties should be is a matter upon which engineers themselves are not agreed, and one on which no two companies or manufacturers will agree. It must depend upon what is the best practice and what should be omitted or contained in the contracts and specifications are matters too broad and too technical to be treated in a few magazine articles. It is a subject in which experts of the profession of engineering, architecture and law have spent lifetimes to understand and to put to the best use and service, and it involves the whole subject of professional skill, knowledge, training, and experience, and one in which no two engineers, architects or attorneys will agree entirely.

The object of this article has been to give to contractors and engineers, builders and architects, some ideas (1) of what the contract and specifications should contain; (2) in regard to how they shall interpret and apply the contracts and specifications; (3) how the courts have heretofore interpreted the intention of the parties as expressed in certain language in certain cases; and (4) to impress upon the minds of all the importance of expressing their intention so clearly that the court will have no difficulty in arriving at that intention. The author hopes that he may have accomplished these four purposes.

JOHN CASSAN WAIT.

NICKEL-STEEL RIVETS.

SOME very interesting and important experiments were recently made at the works of the Bethlehem Iron Company, South Bethlehem, Pa., by the engineer of tests, Mr. Manusel White, for the purpose not only of ascertaining the reliability and comparative efficiency of nickel steel for general riveting, but also to observe the effects of working rivets of this material at different degrees of heat. This latter point is one which was most desirable to have experimental data upon, and the results which Mr. White obtained are such as to remove all doubt as to the possibility of working these rivets safely within perfectly reasonable limits, and with the exercise of only ordinary care.

In preparing for these tests, two samples of the steel were taken from two different heats of different composition. From these samples, round bars of ¾-inch diameter were rolled, and from the bars were forged a number of ¾-inch rivets of standard shape. The rivets of each heat were given a distinguishing mark, No. 1 and No. 2, so that failure of any rivet could be traced to its heat and composition.

In order to establish the effect which different degrees of heating the rivets for driving would have on their strength and reliability in shearing tests, the test-pieces were riveted up with the rivets at from obviously different temperatures, and indicated by letter, as follows:

A—Bright cherry red.
B—Light red.
C—Yellow.
D—Almost white.

Each test-piece was marked both with the letter and figure representing the heat from which the rivet was made and the temperature at which it was driven. In the first lot of test-pieces the rivets were in single shear, as shown in Fig. 1, the plates being ½-inch steel and the center of the holes 1¾ inches from the edges of the plates.

The results of this first series of tests were as follows:

¾-INCH NICKEL-STEEL RIVETS—SINGLE SHEAR.

Mark.	Breaking load.	Nature of fracture.	Shearing load per sq. inch on rivets.
1 A	84,800	Plate broke	88,330
1 B	87,600	Rivets sheared	91,240
1 C	80,700	Rivets sheared	84,060
1 D	78,400	Rivets sheared	81,660
2 A	70,600	Heads broke off	73,530
2 B	85,700	Plate broke	89,270
2 C	90,900	Heads broke off	94,680
2 D	79,700	Heads broke off	83,000

A photograph of this series is given here, from which the elongation of the holes in the plate can be seen. To readily understand this illustration,

NICKEL-STEEL RIVETS, SINGLE-SHEAR TESTS.

NICKEL-STEEL RIVETS, DOUBLE SHEAR TESTS.

it may be pointed out that the upper two test-pieces are *iron* rivet tests, alluded to later on, and that the lower four on each side comprise the pieces tabulated above. The broken ends of rivets in 2 A, 2 C, and 2 D are laid on the upper plate.

As it was noticed that the plates were excessively bent in the cases of No. 2 rivets where the heads of rivets were broken off, shown in Fig. 2, another series of tests was arranged, in which this cause of failure of the rivet would be removed. The plates were arranged as shown in Fig. 3, so as to bring the rivets in double shear, and the same marks were used as before, only in this case the two rivets in the same plate were driven at different heats, in order to trace failure of either to the higher or lower heat. In four joints, A and B heats were used, while in the other four, C and D heats.

The results of this second series, double-shear tests, were as follows:

¾-INCH NICKEL-STEEL RIVETS—DOUBLE SHEAR.

Mark.	Breaking load.	Nature of fracture.	Shearing load per sq. inch on rivets.
1 AB	78,550	Plate sheared	87,200
1 AB	81,600	Rivet broke one side	90,550
1 CD	83,800	Plate sheared	93,100
1 CD	74,050	Rivet sheared	82,270
2 AB	84,200	Plate sheared	93,550
2 AB	82,640	Plate sheared	91,820
2 CD	79,800	Plate sheared	88,660
2 CD	84,100	Plate sheared	93,440

The second photograph shows graphically these results. As in the first photograph, the plate that pulled away or failed is laid over and covers the other plate, for convenience in photographing, so that 2 A B, for instance, is one of the middle plates which pulled out from the rivet farthest from it in the photograph, on the adjoining welt plate.

A study of the illustrations in connection with the tabular data is interesting and profitable.

In order to make some comparison between nickel steel and the ordinary steel rivets, two test-pieces were made with ⅞-inch common steel rivets, and were marked E and F. In single shear, ½-inch steel plate was used, with holes 2 inches from edge of plate. In double shear, ⅝-inch steel plate was used, with ⅜-inch steel plate welts, and the holes 2 inches from the edge. The results were:

⅞-INCH COMMON STEEL RIVETS.

Mark.	Breaking load.	Fracture.	Shearing load per sq. inch on rivets.
E	53,200	Rivets sheared	43,600 single shear.
F	55,100	Rivets sheared	46,000 double shear.

From these results, Mr. White notes that it may be safely deduced that a ¾-inch nickel-steel rivet will replace a 1 $\frac{1}{16}$ inch, or even possibly a 1⅛-

inch, common steel rivet, thus affecting a saving of considerable plate section, and giving increased strength.

The experiments show that while the maximum strength is not obtained in nickel steel by using too high temperature as a working heat, the higher temperatures here used did not seriously injure the material. It would, of course, be an easy matter to adjust to the proper heat within close limits

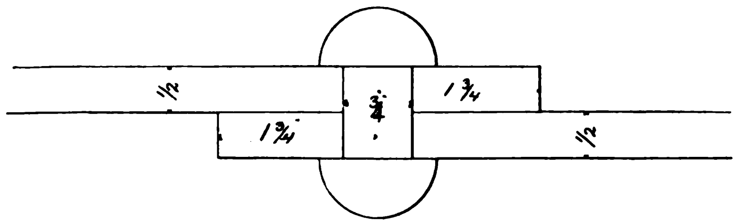


Fig. 1.

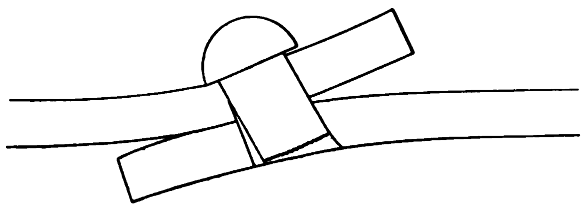


Fig. 2.

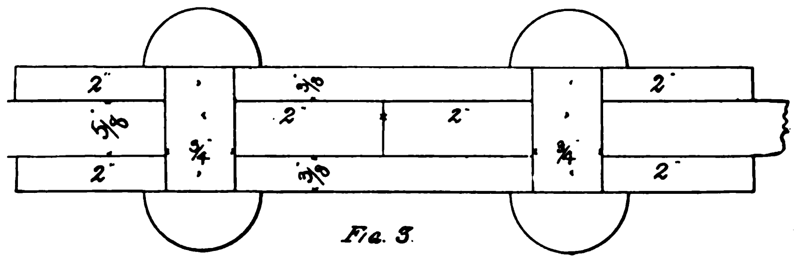


Fig. 3.

ARRANGEMENT OF PLATES FOR TESTS.

by exercise of a little care. It was found, in heading up the rivets, especially at the lower heats, that more resistance was offered to forming the heads than by common steel rivets. The heads were formed by the sledge and cup set. No heads flew off, as is often the case with ordinary steel rivets, giving additional proof of the superior toughness of nickel steel.

The above summary of Mr. White's report can be supplemented here very appropriately by a table of tests of nickel steel made at Homestead Steel Works. The data is self-explanatory, and well worth careful inspec-

TESTS OF NICKEL STEEL.

Steel Maker, Carnegie Steel Co. Rolled by Homestead Steel Works.

Kind of material.	Marks.	Chemical analysis. C.	S.	M.	Nickel.	P.	Original section. Diameter.	Area.	Fractured area.	Elastic limit, per sq. inch of original section.	Ultimate strength per square inch of original section.	Elongation, per cent in 8 inches.	Reduction of area, per cent.	Remarks.
Rods.	1	.23	.017	.61	3.22	.021	.750	.4418	.1772	48,440	82,390	22.5	59.9	Original.
Rods.	2	--	---	--	---	---	.750	.4418	.1698	47,760	79,910	22.5	61.6	Red heat.
Rods.	5	--	---	--	---	---	.750	.4418	.1698	46,400	82,170	22.5	61.6	Bright red.
Rods.	6	--	---	--	---	---	.750	.4418	.1772	55,460	83,980	21.25	59.9	White heat.
Rods.	7	--	---	--	---	---	.750	.4418	.1886	53,880	86,700	17.5	57.3	Bright white heat.
Plate.	1	.28	.025	.52	3 70	.011	1.000	.7854	.3217	-----	87,470	19	59.1	Original.
Plate.	2	--	---	--	---	---	1.000	.7854	.3267	48,510	89,260	19.5	58.4	Dark red.
Plate.	3	--	---	--	---	---	1.005	.7933	.3370	48,160	82,950	23.25	57.6	Bright red.
Plate.	4	--	---	--	---	---	1.003	.7901	.3794	49,230	85,940	22.25	52	White heat.
Plate.	5	--	---	--	---	---	1.000	.7854	.5281	49,660	93,070	15.62	32.8	Bright white heat.
Rods.	1	.23	.017	.61	3 22	.021	.855	.5741	.2165	56,970	81,710	23.75	62.3	Original.
Rods.	2	--	---	--	---	---	.750	.4418	.1590	55,460	81,490	24.5	64	Dark red.
Rods.	2	--	---	--	---	---	.750	.4418	.1626	56,370	82,390	21.75	63.2	Dark red.
Rods.	3	--	---	--	---	---	.750	.4418	.1662	58,410	83,980	23	62.4	Bright red.
Rods.	3	--	---	--	---	---	.752	.4441	.1698	59,010	83,780	22	61.8	Bright red.
Rods.	4	--	---	--	---	---	.750	.4418	.2083	59,760	93,030	16.25	52.9	White heat.
Rods.	4	--	---	--	---	---	.750	.4418	.1924	60,670	91,220	17.75	56.4	White heat.
Rods.	5	--	---	--	---	---	.750	.4418	.2043	62,700	91,670	15	53.8	Bright white heat.
Rods.	5	--	---	--	---	---	.750	.4418	.2463	61,580	93,930	17.25	44.3	Bright white heat.
Rods.	1	--	---	--	---	---	.855	.5741	.2333	57,150	82,920	22.75	59.4	Original.
Rods.	2	--	---	--	---	---	.747	.4383	.1735	64,580	87,610	21.75	60.4	Red heat.
Rods.	2	--	---	--	---	---	.750	.4418	.1772	58,180	84,550	21.87	59.9	Red heat.
Rods.	3	--	---	--	---	---	.750	.4418	.1772	62,930	86,700	22.63	59.9	Bright red.
Rods.	3	--	---	--	---	---	.749	.4407	.1735	66,260	86,010	23.75	60.7	Bright red.
Rods.	4	--	---	--	--	---	.749	.4407	.2165	73,080	94,860	16.5	50.9	White heat.
Rods.	4	--	---	--	---	---	.749	.4407	.2043	68,540	92,800	16.5	53.7	White heat.
Rods.	5	--	---	--	---	---	.749	.4407	.2043	66,950	93,030	16.5	53.7	Bright white heat.
Rods.	5	--	---	--	---	---	.750	.4418	.2003	68,140	91,000	13	54.7	Bright white heat.

tion. The field of usefulness of this extraordinary material is rapidly extending, and there is no reason why it should not meet the requirements of many parts of machinery to which, as yet, it has not been applied.

—*Journal Am. Soc. Nav. Eng.*

THE ARCHITECTURE OF BRIDGES.

IN OUR April issue we called attention to the lack of an attic story on some notable suspension bridge towers, having in mind the East River bridge. The following article, from the pen of Emily Warren Roebling, in the New York *Mail and Express* of recent date, explains what may have been known to some, but which was a mystery to many:

"*The Mail and Express* on February 4th published a photograph entitled 'The Busiest Bridge in the World.' The point from which the very interesting picture was taken served to emphasize, in my mind, the regret I feel whenever I look at the unfinished tops of the towers. I have hoped from time to time in the sixteen years that have rolled by since the structure was thrown open for public use that this architectural defect would appeal to the taste of someone in authority, and that the ornamental parapets would be put on the towers.

"There have been several presidents of the boards of trustees of the bridge company; uncounted numbers of these same trustees, many mayors of the two cities, and now a Commissioner of the City's bridges, but I have waited in vain for any of them to take an interest in adding this finishing touch to an engineering monument which has been much admired as an artistic ornament to the city, as it has been appreciated for its usefulness. Mr. Wilhelm Hildenbrand, the assistant engineer of the Brooklyn bridge, in whose hands were placed by Colonel Roebling the working out of all the detailed plans used on the bridge during its construction, has sent me the following letter in answer to some inquiries I made of him on this subject. His words would undoubtedly have more weight than mine in convincing the public that this finishing work is both practical and inexpensive:

COVINGTON, KY.

My Dear Mrs. Roebling—I take pleasure in returning to you your large picture of the Brooklyn Bridge, on which I have painted, by your request, the stone parapets on top of the towers, which are necessary to give an architectural finish thereto, but which have never been erected, though they are a part of the original plan, and equally, if not more important, a feature of the architecture than the parapets around the towers at the level of the roadways or the beadcourse at the springing line of the pointed arches. The only reason, as far as I can remember, why this parapet was not built in 1883, was the scarcity of funds at the time of the completion of the bridge. The money on hand was used in preparations for the impressive opening ceremonies, and the erection of the parapets was postponed to a more propitious time.

The parapets, as sketched on your picture, are an exact copy of Col. Roebling's original design.

I have among my papers the specifications which I drew up by order of Col. Roebling, and from which I will quote: "The total height of the parapet was to be seven feet six inches, and the thickness of the shaft (between caps and base) was to be eighteen inches. The stone was to be dark granite; the workmanship to be six-cut work for the faces and fine pointed for the rear. The total quantity required for both towers amounts, under the original design, to 348 cubic yards."

I believe $7,540 would be a liberal estimate of the cost of this work. Hoping that my description and drawing will suit your purpose, I am truly yours,

WILHELM HILDENBRAND,

Formerly assistant engineer New York and Brooklyn Bridge; at present chief engineer Covington and Cincinnati Suspension Bridge.

"The only way I know of arousing public interest in any project is to appeal to the newspapers to use their influence. I wish that we might see the Brooklyn bridge finished before the opening of the new century.

"I would also like your invaluable aid in correcting some popular misapprehensions in regard to the engineer of the bridge. The impression is almost universal that Col. Washington A. Roebling finished the work which was begun by his father. The facts are that when Mr. John A. Roebling died, in July, 1869, not a stroke of work had been done on the Brooklyn bridge, but it was just where the great North River bridges are to-day—on paper.

"Any one by referring to a file of old Brooklyn newspapers of the summer of 1869 can read that at a meeting of the bridge incorporators, called almost immediately after the death of Mr. John A. Roebling, President Henry C. Murphy said:

"'Mr. John A. Roebling during his lifetime had employed as his assistant

THE GROSVENOR BRIDGE.

in this enterprise his son, Washington A., a young man of great promise, only 33 years of age. Mr. John A. Roebling has often told me that his son Washington was the only living engineer who could carry the work through to a successful termination. All who knew young Roebling spoke of him in the highest manner, and extolled his abilities as an engineer.'

"In reply to a member who asked if it was imperative on the corporators to elect a successor so soon, the chairman replied in the affirmative, stating that one of the foundations should be begun at once. On motion of Mr. Jenks, seconded by Mr. Green, it was unanimously resolved to elect Col. Washington A. Roebling chief engineer to build the bridge.

"The first actual work done in connection with the bridge was awarding the contract for building the caisson for the foundation of the Brooklyn tower to the firm of Webb & Bell, of Greenpoint, on the 25th day of October, 1869, three months after the death of Mr. John A. Roebling.

"Excavations for this caisson were begun in January, 1870, but the caisson was not launched until March 19, 1870.

WEST TOWER OF BROOKLYN BRIDGE.
The parapet which appears in the illustration was a part of the original plan, but has never been built.

"People often say to me: 'I frequently met the late Mr. John A. Roebling when he was on the Brooklyn bridge.' This is owing to the confusion so common in the names of father and son. Any person who ever met a Roebling on the Brooklyn bridge during its construction saw Col. Washington A. Roebling, as he is the only Roebling who was ever on the work. He has been a great invalid, but is as well to-day as most men of his age, and as active.

"Another error which I have occasion often to correct is that the John A. Roebling's Sons Company, of Trenton, N. J, built the Brooklyn bridge. In rea'ity, that company is not a bridge-building company, but manufacturers of wire and wire rope. They never furnished anything to the Brooklyn bridge but wire ropes on reels, which were cut off into the lengths required for stays and suspenders under the orders of the staff of the bridge engineering department.

The sockets and fastenings for the stays and suspenders were made in Pittsburg and put on at the bridge. J. Lloyd Haigh furnished under contract the wire for the big cables, which were made under the careful supervision of Colonel Roebling's assistants. The Edgemoor Company, of Wilmington, Del., had the contract for the steel for the superstructure, used in floor beams and trusses, but these were all erected by the engineers of the bridge company, the Edgemoor Company simply furnishing the shapes. Most of the statements of different parties having erected the Brooklyn bridge on contract I think could be traced to irresponsible commercial travelers, who do not always stick closely to facts when they wish to advertise the firm whose goods they are trying to sell.

"It makes me sad when I read in critical journals all the defects in the plans and construction of the Brooklyn bridge, but when I think of all the opposition it has lived down, and how much more it is doing that its most ardent admirers ever hoped for it, I wish, with all its imperfections on its head, its stay system, its slip joint, its lack of bicycle accommodations, etc., the authorities of Greater New York would crown the unfinished towers with their graceful parapets and bestow on it the name 'Roebling Bridge,' for so it must ever be called by those who know its history and can appreciate the faith that sustained the engineer in trials such as have come to but few men who have had large public interests intrusted to them."

The Grosvenor bridge, at Chester, England, was also the subject of criticism, and Mr. A. D. Ottewell, of Derby, who has recently visited the bridge, sends us the view we reproduce, together with the following remarks:

"Being in Chester the other day, and seeing the enclosed photograph, thought it might prove of interest to you and readers of BRIDGES. I have no doubt there is a great deal of justice in your criticisms of the bridge. Still, when observing it, I could not help feeling considerable respect for the man who conceived and the men who built the arch."

Our criticism is more elaborately expressed in the following extract from Fergusson's "History of Modern Architecture":

"As an engineering work, nothing can be nobler. It is the largest single span, for a stone bridge, in England, probably in the world, built of the best materials, and in a situation where nothing interferes with its beauty or proportions. Its engineer, however, aspired to be architect, and the consequence is that, instead of giving value to an arch of 200 feet span, no one can, by mere inspection, believe that it is more than half that width. In the first place, he introduced a common architrave moulding round the arch, such as is usually employed in domestic architecture, and which it requires immense thought to exaggerate beyond the dimensions of a porte-cochère. He then placed in the spandrils a panel 30 feet by 50, which in like manner we are accustomed to, of one-third or one-thirtieth of these dimensions. He then, on his abutments, introduced two niches for statues, which is immediately assumed would be life size, and beyond this, two land-arches without mouldings or accentuation of any sort, consequently looking so weak as to satisfy the mind there was no difficulty in the construction.

"Had Mr. Harrison been really an architect, he would have rusticated these land arches with Cyclopean massiveness, not only to continue the idea of an embankment, but also to give strength where it was apparently most needed, and would have avoided anything in the abutments that savored of life-size sculpture or of temple building. A mediæval architect would have pierced these spandrils with openings, thereby giving both lightness and dimensions to this part; or, if it was not mechanically admissible, he would have divided it into three or four panels, in accordance with the construction. The essential parts in the construction of a bridge, however, are the voussoirs of the arch, and to this the architect's whole attention should first be turned. If there had been fifty well-defined arch-stones, the bridge would have looked infinitely larger than it now appears. With one hundred it would have looked still larger, but if too numerous there is a danger of the structure losing that megalithic character which is almost as actual dimensions for greatness of effect. The true architect is the man who can weigh these various conditions one against the other, and strike a judicious balance between the different elements at his command. At Chester the builder has failed in this at every point, and by the same process which ruined St. Peter's. By exaggerating his details, the bridge has been dwarfed in exactly the same manner as the basilica.

"If this is all that can be done with bridges, it is far better that they should be left, like most of those recently built, to tell their own tale without any ornament whatever. A long series of tall arches is so beautiful an object in itself that it is difficult to injure it, but occasionally a slight moulding at the

impost, a bold accentuation of the arch, and bold markings of the roadway render those beautiful which otherwise may be only useful in appearance."

We give another criticism of the same bridge, which appears in an essay in Weale's work on "Bridges," by William Hosking, F.S.A.:

"It is impossible to contemplate the Grosvenor bridge over the Dee at Chester without regretting that the great span of its single arch (200 feet) had not been either so much flatter as to raise the springings out of reach of flood waters, as the situation of the bridge does not render the height of the roadway objectionable; or in the more pleasing form of an ellipse rising from its present springing level; or, indeed, it might, with greater advantage, have taken the peculiar form of that singularly graceful variety of the ellipse which is found in the arches of the bridge of the Most Holy Trinity (Ponte della Santissima Trinita) over the Arno at Florence. The rise from the springing level to that of the crown in this example is but little more than one-sixth of the span, whilst the rise of the Grosvenor bridge arch is but in the same proportion less than one-fifth of its span, so that the form of the Florentine bridge might have been obtained in that at Chester, with a much higher line of springing."

LIMES, MORTARS, CEMENTS AND CONCRETES.

LIME, in one form or another, has been employed in building operations from the earliest historical period down to the present time, and bids fair to be so employed so long as man requires a habitation to dwell in. It makes one of our cleanest, efficient, and most healthful mediums for the joining together of bricks, stones, or concrete blocks, and is, besides, the most economical of all known cements and the least refractory to handle.

Lime, such as is employed in the making of common mortar, is produced by the calcination, or burning, of limestones of varying qualities, some stones being almost pure carbonate, such as white chalk and marble, while others contain as much as ten per cent or more of impurities, such as alumina or clay, silica, oxide of manganese, magnesia and traces of alkalies, and it is the measure of these impurities that fixes the quality of the lime. I believe that limestones of more or less value are to be found in every state of the Union and in every province of the Dominion of Canada. As the limes differ in the various localities, the engineer or architect should assure himself as to whether it is suited to his purpose before he proceeds to make use of it.

A good lime should possess the following qualities: When delivered, it should be in hard lumps, free from slaked particles or dust. There should be no cinders or clinkers in it, nor should there be more than ten per cent of other impurities in it. It should slake readily in water, forming a very fine smooth paste, without any residue. It should dissolve freely in soft water. Lime that leaves kernels of stones and traces of silica and alumina when "run off" should not be employed for plastering, but may be used in common masonry and brickwork with fairly good results.

In some parts of the United States and Western Canada, the limes leave a residue of stones, gravel and lumps of hard clay undissolved after being slaked, and it is therefore necessary to mix the lime in a box which is elevated above a second box, in order that the slaked lime may be "run off" from the first box, passing through a screen to prevent the impurities getting into the lower box. The lime in its raw state is placed in the upper box, and water then is supplied over it as the lime slakes until the whole mass, when thoroughly mixed, assumes the consistency of cream, after which the shutter which covers the screen at the end of the box is removed, and the fluid lime drains into the lower box, where it remains until such time as it is required for use. In a day or two after it is drawn off from the upper box, it assumes a pastelike consistency, and is free from sand or gritty substances, has a smooth and oily feel when rubbed between the finger and thumb. In this state the mixture is called "putty," and it is in a proper condition to be so mixed with sand as to be suitable for the mason or for the plasterer. In order to secure a proper state of the hydrate, or slaked lime, it is important that neither too much nor too little water be thrown on the lime while being slaked. If too little water be used the lime "burns" or becomes partially dry while slaking, and small portions of it remain unslaked for want of moisture

and render the mortar when made in that state, unfit for use. On the other hand, when too much water is added, the mass becomes "chilled" or "drowned," and large portions of the lumps of lime slake so slowly or not at all, which is a very serious matter if the mass be made into mortar. Too much water also, according to Vicat, reduces the strength of lime about two-fifths, and mortar made from it becomes "rotten" and has but little adhesive qualities. Just enough water should be used at first to start the slaking process and keep the lime moist, and as the slaking proceeds more water should be added and the lime kept moist. When the slaking process is fairly advanced, a little more water may be applied and the whole mass stirred up with a lime-rake, or a hoe that has its blade perforated with holes. Quick slaking, or fiery lime, may be kept covered with water from the very first to prevent its burning, and it should be stirred up as much as possible or it will be sure to scorch in some places. It should be remembered that warm water will slake lime much quicker than cold water, and some experimentalists assert that lime slaked by aid of hot water is much stronger and will set harder, than when slaked with cold water. In my experience I have not found such to be the case to any appreciable extent.

The calcination of any pure variety of limestone will produce quicklime "by expelling from the carbonate of lime (CaO. CO_2), of which they are essentially composed, the carbonic acid gas (CO_2), water of crystallization, and organic coloring matter. Lime is therefore a protoxide of calcium, or in other words, a metallic oxide, the base, calcium, having been classed, since Sir H. Davy succeeded in effecting the decomposition of lime, among the metals. Pure lime (CaO) has a specific gravity of 2.3, is amorphous, somewhat spongy, highly caustic, quite infusible, possesses great avidity for water, and, if brought in contact with it, will rapidly absorb .22 to .23 of its weight, passing into the condition of hydrate of lime, a chemical, of which the formula is C_2O, HO. The reactions resulting from this combination are attended with certain marked phenomena, such as a great elevation of temperature, the bursting of the lime into pieces with a hissing and crackling noise, the evolution of a hot and slightly caustic vapor, and finally, after a few minutes, its reduction into an impalpable powder, of which the volume is about three and a half times of the original lime. In this condition the lime is said to be slaked."—(Gillmore).

According to Sir Humphrey Davy, water dissolves about one four-hundredths of its weight in lime, or, according to Thompson, one seven hundred and fifty-eighth, while Dalton states it to be at 60 deg. F., one seven hundred and seventy-eighth, and, at 212 deg., one twelve hundred and seventieth.

On account of its great affinity for moisture, and when moist, for carbonic acid, lime absorbs them gradually from the atmosphere, and eventually returns to the state of carbonate of lime, with an excess of hydrated base, and, to protect it against these deteriorating agents, it should be packed in airtight cases of some sort.

Lime mortar, or lime cement, though it may have been used sparingly in remote times, was occasionally employed, as we have evidence of its high antiquity. The walls of the Acropolis of Pharsalia, and at other places, exhibit an unusual thickness, and are lined on both sides with large blocks; yet the interstices are filled up with small stones, and with earth or lime mortar. Again, the walls of Methana are constructed with a compact mass

of small stone, with lime mortar, tiles and earth between casings of regular masonry. The Greeks, in their art of building, cultivated the faculty of joining their large stones in such a skillful manner that they seem for a long time to have discarded the use of mortar as a binding medium. Whenever they did use it, they appear to have applied it in very thin layers. It was necessary for the Greeks, in their massive and matchless buildings, to make very close joints, and they often brought the surface of their stones so close that the points of union were not observable without the keenest inspection. Stones or lengths of masonry were often fixed together by means of oaken dowels, pegs, bolts, or by clamp-irons let in or dovetailed. In the Coliseum at Rome, and in the Amphitheatre at Verona, clamp-irons were used to hold the freestone firmly, but no mortar. One architectural authority is of opinion that it is possible "that mortar might have been used of a nature sufficiently fine and subtle to blend and assimilate itself in course of time to the masses of which it formed the cement." The Roman method of making ordinary building mortar did not differ greatly from the methods employed by builders of the Middle Ages. It is stated by some authorities that the burning of stone into lime was not brought into general use until about three centuries before the Christian era, and that previous to that time most of the buildings of any importance were built with stones or bricks, cemented together with bitumen, or pitch, or held together with dowels, pegs, or clamps, as before described. The sun-dried bricks used in the building of the tower of Babel are stated to have been cemented with bitumen or pitch, and this and other materials were used in different countries for centuries subsequently. After lime mortar had been used for a time, builders recognized its good qualities and soon began to make use of it profusely, both on account of its excellent cementing qualities and as a matter of economy, and the Romans applied it with a liberal hand in the body of their walls, the lime being generally burned on the spot, and used fresh before cooling and crystallization set in. When once the use of lime-mortar became known among the Romans, they used it in all kinds of masonry and brickwork; indeed, some of their rough stone or rubble walls were, in fact, a species of concrete construction through the ample use made of the mortar they employed. Both Roman and Greek made use of wooden dowels and clamps of metal, as did also the earlier Etruscans, as well as mortar, in the construction of their walls.

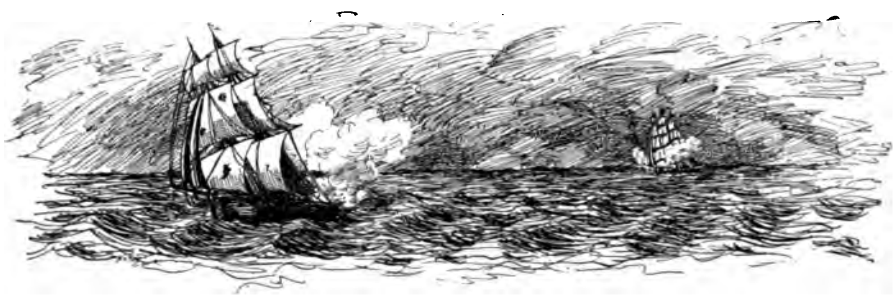
In the British Islands, the earliest, or prehistoric structures, including Cashel or stone-built forts, clochans, or bee-hive shaped erections, and raths are all of dry-wall masonry, but many of them exhibit good fitting and bonding, though no cementing was used in their construction. Some of the rath-chambers, which are the oldest examples of stonework in the British Isles, are fine specimens of rough stonework laid up dry. The walls in some instances are built of surface stones and bowlders and the interstices are filled up with spawls well packed in; in other cases flat longitudinal stones are carefully placed together, and again large blocks of all sizes and shapes are found well fitted in their natural forms. Indeed, there are examples of this class of buildings presenting masonry work of excellent character, well bonded and fitted, and showing to some extent an appearance of squaring and dressing.

With the advent of the Romans under Cæsar, the use of lime mortar in the islands became quite common, as some works, yet extant, testify; but

whether the use of lime-mortar was known to the Britons before the Roman invasion, is a question that will likely forever remain unsolved. However, whether the early Gaelic and British masons were skilled in the use of mortar or other cementing materials or not, they were certainly skilled in the more difficult art of preparing and fitting the stone. The structures in Ireland and Scotland, known as the Round Towers, show evidences of the use of mortar, and if, as many assert, these towers were erected in pagan times, it is possible that a knowledge of the uses of lime-mortar had reached those countries before the Romans invaded the greater isle, a probability that is very likely when we know that travelers from Ireland often visited the Continent.

FRED T. HODGSON,
Architect.

(To be continued.)



BRITTLENESS PRODUCED IN SOFT STEEL BY ANNEALING.*

IN a previous paper by the writer, on the "Crystalline Structure of Iron," it was shown that under certain conditions soft steel sheets containing between 0.05 per cent and 0.12 per cent carbon, on close annealing for forty-eight hours occasionally developed an extraordinary tendency to become most readily fractured on the application of a sudden blow, or when they were hammered or dished into shape.

It is the writer's object in the present note to discuss more fully this peculiarity, and to present further facts bearing upon the subject. This title of the paper referred to probably justified the supposition by practical men that the matter contained therein was of purely academical interest, and in all probability little notice was paid to it. As a matter of fact, it contained much that was of a practical character, and many facts relating to the treatment of steel which metallurgists would do well seriously to consider. It must be admitted, however, that there was given a considerable amount of matter about which the busy men in our steel works would not care to trouble themselves. This note is more purely of a practical character, written so that all working metallurgists may fully understand and appreciate the great importance of the question discussed.

In order to make the data presented complete, it will be necessary to recapitulate the main facts given in the previous paper which bear upon the development of brittleness in soft steel by annealing.

The Terms used to Describe the Structure of Iron and Steel.—In iron, and in almost all metals, bright polished surfaces, on being etched by suitable reagents, are broken up into irregular polygonal masses, and resemble more or less perfectly mosaic which has been laid with stones of no regular form. Each polygonal area in metals represents the section of a crystal, the true terminal angles of which at the time they grew or were developed not being able to form owing to mutual interference of growing contiguous crystals. These polygonal areas in reality represent the grains or crystals seen on any rapidly fractured surface of a metal.

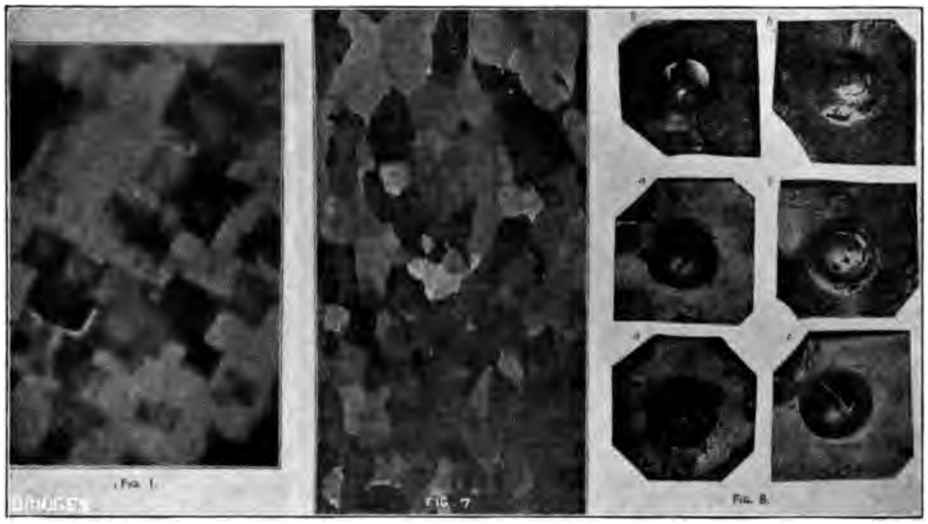
Practical men commonly describe such fractures in steel of "coarse" or "fine" structure as "finely" or "coarsely crystalline," but the terms "fine" or "coarse grained" are also used. Some engineers call a fine structure "granular," and a coarse one in which large bright faces are visible as "crystalline." We must remember, however, that whether the crystalline grains in a metal are large or small, the metal as a whole is equally crystalline, the only difference being that there are a greater number of separate individuals in one case than in the other. The polygonal masses of irregular shape when completely isolated much more resemble grains than crystals, and it appears more reasonable to call them the former than the latter. To be more exact, the term "crystalline grain" correctly expresses their character. As long, however, as it is clearly understood what is meant by terms, it is not of great importance which is used.

* Paper read before the Iron and Steel Institute; Stockholm meeting.

In the remarks which follow the term "grain" will be used instead of crystal, and it must be understood to mean a grain the mass of which is crystalline, the molecular crystals of which it is built being all of same orientation in the whole of its mass.

It has been repeatedly proved that many cubic crystals of minerals possess the property of being split up more readily in some directions than in others, and these are always at right angles to and parallel with a cube face. It will be seen, then, that the number of directions in which a true cube crystal can be split must be three, all of which are right angles to each other. The property of crystals to split up in this peculiar way is what mineralogists call cleavage.

Iron crystallizes in the cubic system, and the crystalline mass of every separate grain in a bar of iron is more liable to split up in these three directions than in any other. When we talk of the orientation of the crystals of a



metal, we mean the direction of their cleavage planes, and their relation to each other in the crystalline granules of which the metal is an aggregation.

Now, these remarks may be considered as elementary, and probably by the younger members, who have had the advantage of a full scientific training, as superfluous; but we must not forget that there are thousands of good, practical, useful men who never heard of crystallography, and it is for their benefit they are made; and when it is known that, for all practical purposes at any rate, it is not necessary to know more of crystallography than what has been here given, it is to be hoped the men about our works will not have any difficulty in grasping such elementary truths.

Inter-Granular Weakness.—The introduction of the microscope and the application of the methods described by the writer for the micro-mechanical examination of sections of metal, now enable us to determine with almost certainty the exact seat of the weakness in a metal, and to determine its character.

There are two distinct characters:

The first, where the weakness is located between the grains of the metal,

that is, where the grains join each other. When such a metal is broken up, the line or direction of the fracture follows the junctions of the grains. This character of weakness we call "inter-granular," that is to say, between the granules. Sometimes the grains of metal do not actually come in contact, but are separated by envelopes of substances which separate out when the metal solidifies or is slowly cooled.

Professor Arnold's very beautiful researches on the influence of small quantities of impurity on the mechanical and structural properties of gold and copper have shown us many instances of such granular envelopments, and the researches of Osmond and myself have fully confirmed that gentleman's work.

On testing mechanically the small polished and etched microsections of such classes of metals, by placing them face downward on a dished block of lead or other metal and striking them with a blunted center punch in the middle portion of the back, so as to effect a partial or complete fracture of the specimen, and when the now broken section is reëxamined under the microscope, the line of fracture almost invariably will be seen to traverse through the foreign matter between the grains.

The alloy of copper with a very little bismuth in which the grains of copper are enveloped with a brittle constituent is an excellent example of inter-granular weakness.

Professor Arnold has found that occasionally in steel castings the grains are more or less enveloped with an easily fusible scoriaceous matter, and the writer has proved, as was rightly assumed by Arnold, that the line of fracture actually follows the scoriaceous envelopes. The hard white and brittle envelopes of carbide of iron which surround the grains in steel containing above 1 per cent of carbon, are the principal lines of weakness, and it is through the center of these brittle envelopes the fracture mainly travels when the steel is broken.

There is another character of inter-granular weakness, in which, so far as we can see at present with the appliances at command, there is weakness, yet no envelope of a brittle constituent is present. This is particularly marked in certain annealed steels containing phosphorus. Professor Arnold believes that the crystalline grains in the mass of such metal on cooling contract unequally, and tend to draw apart, leaving the junctions not perfectly jointed, or in a state of unnatural tension. Whatever the cause may be, it certainly happens that in such material the fracture follows mainly the granular junctions.

We see, then, that inter-granular weakness may be divided into two main classes:

1. When brittle matter foreign to the character of the mass of the grains envelops them.

2. When the brittle envelope is absent and the grains, from some cause not clearly demonstrated, are not perfectly cohesively united.

Inter-Crystalline Weakness.—The second character of weakness in metals is that in which the weakest line is not between the grains, but is that represented by the true cleavage planes through the mass or body of the grains. Example was given in the paper read at the last meeting, of cubical forms which had been split from a large crystalline grain of phosphoretted carbonless iron. Since then almost pure iron with grains measuring about 1 inch

across have been obtained, which were with almost equal ease split up into similar forms.

As the line of fracture, on mechanically testing a mass or aggregate of crystalline grains, invariably passed through the mass and never followed the junctions of the grains, we have called this character of weakness "intercrystalline," as the fracture passes between the molecular crystals of which the grains are built.

It has been found, when the unpolished cleavage faces of split-up rectangular masses of nearly pure iron are etched with nitric acid, that perfectly square portions of the iron are dissolved away, leaving more or less minute pits or recesses, and these are formed equally on all the six faces. This is very strong evidence that pure iron consists of cubic crystals and not octahedra (Fig. 1, which is magnified 200 diameters).

It has also been found that in a coarsely granular piece of iron, after it has been polished and etched by nitric acid, the different grains reflect light at varying angles. On examining such a plate, held directly in front of the eye, when we have our back to the source of light, such as that from a window, we find that certain grains appear brilliantly illuminated, whereas others vary in brightness, and that on slightly moving the specimen out of its vertical plane the brighter grains become dark, and the dark grains bright, and every movement causes a change.

We find that the grains which reflect back again the rays of light which fall vertically upon them are those which can most readily be broken up by a percussive blow directed through a blunt point behind it, and the fractures usually cross at an angle of 90 degrees. The same grains on deep etching are those which give the most perfect square cavities, readily seen when examined under the microscope. From all this evidence we know that the molecular crystals in these grains have their surfaces parallel with and vertical to the cut surface of the iron section.

In the grains which reflect the rays of light when the surface of the specimen is moved in the manner just described, the faces of the molecular crystals are at an angle more or less acute to that surface. All this is easily followed by the aid of a simple diagram.

Fig. 2 represents diagrammatically the position and orientation of the molecular crystals in a few contiguous grains *A*, *B*, *C*, and *D*. The little squares in each, tilted at various angles, represent the manner in which the little molecular cube crystals may be oriented in a vertical section of pure iron.

In *A* the cubes have their upper faces parallel to the surface.

In *B* they dip at an angle of about 10 degrees.

In *C* they dip at an angle of about 20 degrees.

In *D* they dip at an angle of about 30 degrees.

The upper line represents the etched surface of the section through the faces of the little cubes, some of which are inclined so as to form a series of little steps, just as in reality they are found after polishing and etching.

The thick dark line gives the direction in which fracture would be most readily effected from right to left.

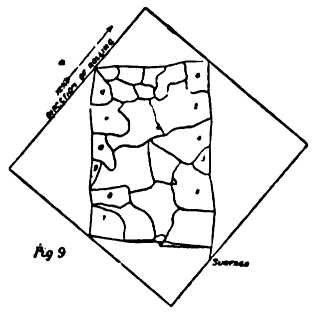
The dotted lines at the upper part represent the angle at which the light must fall in order that it may be reflected vertically. The thin dots represent the incident rays or those which fall on to the surface, the thick dots the reflected rays. The angle made by the incident and reflected rays, divided

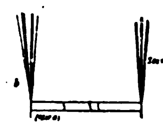
by two, gives the angle of inclination which the upper faces of the molecular crystals bear with relation to the surface of the metal section.

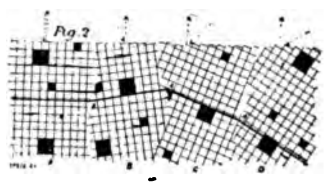
The dark squares, some of which are large and others smaller, illustrate the manner in which the nitric acid selectively digs out or dissolves away perfectly square areas, leaving cavities of greater or less dimensions.

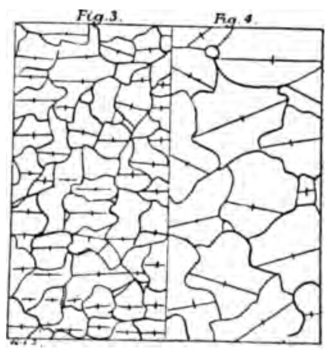
It is to be feared that the purely practical man will be ready to drop the subject at this point, as no doubt, from his view, there is nothing practical

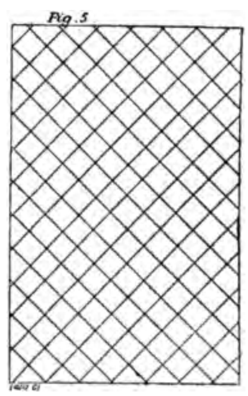
A. FIG. 6 B











in what has just been stated; but let him wait a short time, and it will soon how it is that so-called coarsely crystalline iron and steel are not invariably equally liable to break up.

It has been shown that large grains of pure iron can be readily split up in three directions. It follows that if a mass of iron in a plate or sheet consisted of one single grain built of molecular crystals in the same phase be apparent that without this introduction it would be impossible to explain satisfactorily the peculiar brittleness sometimes produced by annealing, and throughout, such a plate could be readily broken in two main directions,

depending on the axial position of the crystals, one direction being always at right angles to the other.

It is equally clear that if the sheet or plate was built up of grains, either great or small, in which the axial positions of the constituent crystals were nearly but not quite in the same phase in all the separate grains, such a plate or sheet would be weakest and more readily broken in the same two directions. Probably there would be a difference between a small-grained plate and that built of coarser grains, but the difference would be only one of degree, not in direction; the tendency would be to break in rectangular lines in each, but one would more easily break than the other.

It will also be clear that if, in a piece of iron, a few grains near the surface are built up in the manner last described in the same phase, a properly directed force would tend to effect a cleavage at that point, and the cleavage, once started, would travel right through the piece.

On the other hand, if the orientation of adjoining crystalline grains is such that the cleavage plains are at a considerable angle to one another, even if the grains are comparatively large, such a structure would be less liable to break up than a finer grained but symmetrically oriented metal.

This comparison will be understood by the two diagrams on next page.

The crossed lines represent the cleavage planes in each grain. The coarse structure, Fig. 4, represents crystals heterogeneously arranged, whereas, in the finer structure, Fig. 3, they are more symmetrical, and the cleavages run in almost parallel lines. The latter type would be easily broken up, whereas the former would be strong and tough.

It is, of course, well known, all things remaining constant, that it is advisable to obtain structural and other steel as finely grained as possible. The above illustration is only introduced to show that crystalline arrangement may completely reverse this order, so that a coarse-grained metal may be stronger than one of finer grain.

The truth of the foregoing statement has been fully demonstrated in the research of the writer in his experiments at Middlebrough and elsewhere.

It will be seen, then, that brittleness may be caused by the crystals arranging themselves in symmetrical fashion in contiguous grains.

Fortunately, as a rule, in iron and steel they do not grow or build themselves in such order, but are heterogeneously arranged. The illustration, No. 17, in the paper on crystalline iron, gives a type of such a structure. It nevertheless occasionally happens that, under certain conditions, it is otherwise, and the most excellently pure and soft material may be rendered quite brittle, and it is to the study of the conditions which favor such a state of things we must now turn our attention.

Granular Development on Heating Iron to 600 to 750 Degrees Centigrade—It has been shown that on heating practically pure iron in the front part of a laboratory muffle furnace, where the temperature was between 600 and 750 degrees Centigrade, the originally fine grains develop into grains of larger mass; or, to put it in another way, at the temperature of between 600 and 750 degrees Centigrade, the axes at many different angles of several contiguous grains alter their position until they become of the same angle in all, with a coincident disappearance of the granular junctions, the result being a larger grain containing the same mass as the sum of all the masses of the smaller grains added together. Technically expressed, the iron becomes

more or less coarsely crystalline. These changes are not effected rapidly. Time is an important factor, and the conditions usually aimed at to soften and destroy the coarse structure in carbon steels, viz.: long heating at a dull red heat, causes the development of large granules in practically carbonless iron, which may or may not result in the material being brittle. If, for instance, the granules are composed of crystals, the cleavages of which generally lie at right angles to the length and cross-section of a bar of iron, such a bar will be easily broken. If, on the other hand, the cleavages are arranged heterogeneously, although the composition and size of the grains may be equal to the last described, a bar built up in such a fashion will stand comparatively severe punishment without breaking.

Whenever there are large granules, there must be large cleavage planes or lines of weakness; and even although the axial position of the crystalline masses of which the grains are composed may be arranged in the best position to withstand resistance, it stands to reason that a larger number of smaller grains built up in the same way will be much stronger, and stand much greater punishment.

In the laboratory trials of the writer, the coarse granular structure obtained by annealing pure iron at 700 degrees Centigrade could not be broken by a sudden blow; and on examination microscopically the etched grains, sometimes of large dimensions, were found, by the way they reflected light, to have their cleavages at other than right angles to the surface. These samples could be bent over upon themselves without fracture.

It was often found, however, that a coarse-grained bar, after bending to right angles, broke on straightening, whereas the same bar with fine grain could be straightened without breaking.

Although the trials in the laboratory did not give what may be called brittle crystalline iron, it is possible, if they had been repeated, or a sufficient number made, we might in time have obtained one which was so. Occasionally we have met with bars of practically pure Swedish material which were exceedingly brittle, and in which the cleavages were generally at right angles to the outer surfaces. Unfortunately, their previous history and the nature of the mechanical treatment they had been subjected to could not be ascertained, excepting that they had been annealed for a long priod at a temperature under 700 degrees Centigrade, and this was determined with certainty by microscopic examination.

Much work has been done with the endeavor to produce at will material with this brittle crystalline organization, but so far we have not been able invariably to do so. Mr. W. R. Lysaght, of Wolverhampton, has coöperated with the writer, and has done a very large amount of practical work at his suggestion, having annealed hundreds of samples, and rolled many samples of steel under different conditions.

One series of trials was most interesting and instructive.

Several tinplate bars were annealed in a close box for forty-eight hours at about 700 degrees Centigrade. These, when cold, were cut in two, one-half of each being retained for examination, and the others re-annealed for forty-eight hours. These, when cold, were again halved, and portions of each were annealed a third time. All the samples were examined mechanically and microscopically.

The size of the grain in the center of all the bars, after repeated annealing,

was larger than in the same bars before annealing; but, after the first annealing, all the bars were enveloped with a coarsely granular layer. On polishing the surfaces, and then etching with nitric acid, granules measuring up to one-half inch in diameter were revealed.

On attempting to bend them, some of them could be bent close, but others were easily fractured; but all of them, after bending to 60 degrees, on straightening again broke readily.

These samples, on heating to 900 degrees Centigrade, and allowing them to cool naturally, became exceedingly tough. They could be bent backward and forward without breaking. The coarse enveloping layer no longer existed. The simple heat treatment had converted the more or less brittle annealed material into tough and strong steel.

The change after the second annealing was very marked. The external layers of coarse granular steel were transformed into finer-grained material, and now resembled the structure of the central portions, which remained moderately fine-grained throughout after each annealing; but the remarkable feature was that the layer about one-eighth inch below the now finer-grained envelope was coarse grained, the grains being from 5 to 20 diameters greater than those both above and below it. The bars were not so easily broken as they were after the first annealing, as was naturally to be expected, judging from the difference in the character of the external envelopes.

The third annealing did not appear to produce much further change. It was noticed that the weakness of the bars after annealing once was confined to the grossly granular envelope, for, on removing it in a planing-machine, the interior portions were found to be strong and tough. The amount of carbon in these bars varied between 0.08 and 0.12 per cent. The external envelope after annealing contained only traces of carbon, clear enough proof that although the annealing was effected in closed iron boxes, which protected the iron bars from external oxidation, there must have been oxidizing gases present sufficient to oxidize some of the carbon, but which were insufficiently active to oxidize the iron itself to any perceptible degree. Mr. Lysaght has, however, quite recently repeated these experiments, and he has found that the brittle envelope is not always removed by re-annealing.

BRITTLENESS IN ANNEALED SHEETS.

I. *Inter-Crystalline Sheets*—1. The examination of a large number of annealed sheets has revealed the fact that when their thickness is less than 22 B.W.G., brittleness is never developed, and that it is occasionally developed in sheets from 10 to 20 B.W.G.

2. That the preponderating quantity of thicker sheets, which are not readily broken when they leave the annealing pots, and which cannot be classed as brittle, after heating from 400 degrees to 500 degrees Centigrade, and being subjected to jar or shock, which may or may not be sufficient to give a permanent set, almost invariably causes a development of a brittle character. The character of the weakness is sometimes inter-granular, but more frequently inter-crystalline. The lines of weakness in the former take no special direction, and the sheets break up exactly like cast iron. The weakest positions in the second class are invariably in certain fixed directions, viz.; at angles approximating 45 degrees to the direction the sheets were rolled, and at right angles to the surface of the sheets. In other words, the weak lines correspond to the three directions of cleavage in a

cube having four faces at 45 degrees to the edges and two faces parallel to the surface of the sheets.

Such material can be bent and hammered close together when the bending is done longitudinally or at right angles to that direction, but it breaks off readily when bending is attempted at angles of 45 degrees to the direction in which the plates were rolled.

The peculiarity of breaking up in rectangular positions has long been noticed, but it does not appear that notice has before been taken of the invariably fixed relation which exists between the lines of fracture and the direction of rolling.

What is the cause of this peculiar relation?

It is evident that the rolling is the initial cause, but in no case whatever have the rolled sheets previous to annealing shown any tendency to break up in rectangular directions. The rolling of all these sheets is done when the steel is at a comparatively low temperature—about 600 degrees Centigrade—and, as one would naturally expect, a fractured surface invariably presents a fibrous appearance, and the etched polished sections show the same appearance. This is clearly illustrated by the photographs, Fig. 6 (*a*) and (*b*), magnified 30 diameters, of the same sheet, before and after annealing. the rolled sheet *a* is fibrous, the annealed sheet *b*, coarsely granular. The first was not brittle; the second, on very severe punishment, broke with rectangular fracture.

Fig. 8 is a photograph, about half natural size, of the test-pieces which had been subjected to a severe stamping test—*a*, rolled sheet; *b*, after annealing, and *c*, after heating to 900 degrees Centigrade.

We are led to conclude that, just as light impresses a latent image on a bromide photographic plate which cannot be seen, but is developed and made manifest by the action of certain chemical agencies, so the rolling appears to present a latent disposition in the steel to crystallize in certain fixed positions, and annealing develops it afterward.

It is difficult to determine with certainty the exact nature of the change which rolling effects, but, from the general microscopic appearance of etched specimens and fractured surfaces, it would appear that there is a tendency for iron to etch out into thin plates, and when such etched specimens are distorted or are pulled out, for these plates to slide over each other. The rolling of the sheets is at such a temperature that the rolled-out and flattened granules have little opportunity to reorganize themselves into equi-axed polygonal masses before they become cold; and it appears probable that the rolling causes the crystalline plates to slide one over the other, with their angular points generally in the direction in which the sheets are elongated and at right angles to such direction, and that the general position of all the crystals are shown in Fig. 5. When such a sheet is annealed, the crystalline forces begin to act, and at multitudes of centers a systematic marshaling of the minute crystals begins, and the resulting large crystalline masses or grains then have their crystalline axes and cleavages approximating to the same direction of the smaller and more minute grains in the rolled plate.

One very fine example of very gross granulation was met with in an annealed plate. It had been rolled to 16 B.W.G., and afterward annealed for forty-eight hours. It had the following composition:

	Per Cent
Carbon	0.035
Manganese	0.331
Silicon	trace.
Sulphur	0.019
Phosphorus	0.057

It is remarkable for its low sulphur and carbon content. Probably the carbon in the rolled sheet was not less than 0.09 per cent, the difference, 0.055 per cent, having been oxidized in the annealing. Fig. 7 is reproduced from a photograph, natural size, of this sheet, after etching with nitric acid, 1 to 10 water, for ten minutes.

On looking at the original illuminated with vertical light, about one-third of the granules appeared bright, and on moving the plate to angles of 10 degrees in different directions, nearly all the grains became successively bright—a proof that the molecular crystal faces were nearly coincident with the flat surface of the plate. The other crystal faces generally lie at angles of 45 degrees to the direction in which the sheet was rolled, varying from about 40 degrees to 50 degrees. These facts, microscopically determined, were more fully proved by fracturing the specimen and measuring the angles of the cleavage faces. The diagram, Fig. 9 (*a*) and (*b*), illustrates this. It represents another portion of the same sheet as is represented in Fig. 7. The piece in the center of the square was separated by properly directed blows with a hammer. Fractures followed the lines of weakness, and the rough-shaped rectangular piece illustrated was obtained. The vertical cleavages were clean and true, and passed practically from front to back of the plate. It was, therefore, easy to measure the angle of the cleavage face of each fractured crystal grain. The lower sketch represents a section through (*a*), and the lines drawn upward at the ends represent the continuation of the crystal faces of the several grains at each side of the specimen. It will be noticed that the variation is slight, and they approximate closely to right angles to the surface.

There was one small grain at the center of the lower portion with crystal faces at 45 degrees to the surface, and, just as might have been expected, cleavage from opposite sides stopped on each side of this grain, and it was only after bending this grain backward and forward that the two pieces could be separated.

Strips cut from this sheet could be pulled out and elongated nearly 30 per cent before breaking, and stood much punishment supplied in all directions other than at the cleavage lines of weakness.

By heating to 900 degrees Centigrade for one minute, all the peculiarities vanished, and it became fine-grained and tough in every direction.

II. *Inter-Granular Weakness*—There has not been sufficient evidence to enable us to form dogmatic conclusions as to the cause of inter-granular weakness, but in the two or three cases examined the phosphorus was found to be excessive. One very brittle piece contained:

	Per Cent.
Carbon	0.040
Manganese	0.431
Silicon	trace
Sulphur	0.063
Phosphorus	0.263

Re-annealing for forty-eight hours did not restore its good qualities, but it changed its character, the line of fracture traversing both through the grains and at their junctions.

How to Prevent Brittleness—The whole study and work on the subject of crystalline iron was made in order that we might ascertain the conditions leading to the development of brittleness, and so find out what to avoid, and also to ascertain if anything could be done afterward by any special treatment to convert brittle material into steel, tough and reliable. In the more recent investigations of brittle sheets, the following facts have been noted:

1. Occasionally one end of a sheet may be tough and good, and a portion of the other more or less brittle. In one case examined there was found to be no difference in the composition between the two varieties. Presumably we must conclude that the condition of annealing were not absolutely identical. It is difficult to see where or how such a difference could occur, unless we assume that the thermal conditions were unlike and responsible.

2. That sometimes one side of a sheet is brittle, the other being quite tough. Fig 6 (*b*) is an example of this. The photograph was taken along a line 45 degrees to the direction of rolling, and the specimen was illuminated with oblique light. It will be noticed that the inside grains are generally darker than those outside. This indicates cleavage faces nearly in one plane in the grains on the brittle side. This side was brittle, the other was tough.

3. Sometimes the outside is brittle, and the inside tough.

4. There are cases in which the outside envelope is tough, and the inside quite brittle.

These cases where, in the small width of about one-sixteenth inch, there existed both brittle and tough material, must put an end to the supposition that difference in chemical composition is in any way an important factor.

Heating the rolled sheets up to 900 degrees Centigrade, followed by slow cooling, would undoubtedly give tough material; but 900 degrees Centigrade is so high a temperature, the annealing boxes would suffer rapid destruction if heating at so high a degree was adopted.

It will no doubt occur to many that if rolling the sheets in one direction only is the initial cause of rectangular weakness, rolling at various angles, so that one latent impression may be neutralized by a second, that brittleness would be in that way avoided. It would, of course, be impracticable to roll in such a way to any extent, at least without making a circular sheet, and with our present plant it would be impossible. It appears probable, however, that if the last two or three passes were made alternately at angles of, say, 15 degrees in the longitudinal direction, first on one side and then on the other, the tendency to develop brittleness would be greatly reduced, if not eliminated. Such treatment would undoubtedly result in sheets of irregular shape, and a consequent greater production of scrap; it is not likely, therefore, that advantage will be taken of it.

It has already been mentioned that sheets of 22 and higher gauges never develop rectangular brittleness, and that it is only in the thicker sheets it is obtained.

What is the cause of this difference? Does the rolling, continued beyond a certain point, destroy the latent arrangement set up before that point is reached?

This question we cannot answer with our present knowledge.

The whole problem is surrounded with many practical difficulties, and it is certain that until we have means at hand of practically controlling and determining the temperature for forty-eight and more hours of the annealing pots, it will be useless to continue the study. The fact that contiguous parts of the same sheets differ materially in brittleness, the composition being the same in each part, and that different parts of the pots vary in temperature, would lead us to believe that proper temperature is the all-important factor.

The one important point which we may consider to be established is, that phosphorus should not be allowed to exceed about 0.08 per cent.

A sample of steel which was exceedingly brittle in rectangular lines, and which, although it was annealed repeatedly, still maintained its brittle cleavage character, contained:

	Per Cent.
Carbon	0.11
Manganese	0.345
Silicon	trace.
Sulphur	0.090
Phosphorus	0.128

In conclusion, it must be admitted that the study of this most important subject is not only of the highest scientific interest, but of the greatest practical importance. It would be well if more attention was paid to it, and it is hoped that the results recorded in this note will stimulate others to follow up the investigation.

The writer acknowledges with gratitude the valuable coöperation of Mr. W. B. Lysaght.

JOHN EDWARD STEAD.

BUILDING IN REGARD TO EARTHQUAKES.

A METHOD CALCULATED TO AFFORD VERY GREAT SECURITY TO MASONRY STRUCTURES DURING AN EARTHQUAKE.

[Continued from June Number.]

The question of earthquakes has hitherto, and with good reason, seriously occupied the attention of engineers in countries where such phenomena are frequent, and in Japan it is generally believed that wooden structures offer greater resistance than structures in masonry.

We are not entirely of this opinon, for it has always seemed to us that structures in masonry, with very thick walls, made of good material and solidly joisted to the framework of the flooring and roof, afford just as much security against earthquakes, while they are at the same time much more durable than Japanese structures or wooden structures. Nevertheless, and as the contrary opinion has hitherto prevailed in Japan, we have considered that we ought to look for a method to obviate this so-called want of solidity, and we trust that we have obtained a solution as simple and good as it is inexpensive, and which will allow of giving masonry constructions indisputably more resistance than wooden ones.

On account of the greater and greater difficulty on the one hand of getting suitable timber and on the other of the extension given to brick-making in Japan, the price of masonry structures goes down day by day, while that of wood goes up. The great difficulty in taking up masonry construction comes to-day merely from the belief that it does not afford sufficient security during an earthquake.

It would, however, be dangerous to strive to further lessen the difference in price by employing in masonry work material of inferior quality or by lessening the depth of the walls. Economy cannot any more be brought to bear on doing away with the best system of connecting the walls to the framework and to one another. In the one case as in the other the result of this false notion of economy must prove fatal. Whenever you erect a masonry building in a country where there are or where there is fear of earthquakes it is absolutely necessary to have *sound building*, if you wish to be sure of obtaining a greater security than in wooden buildings.

Long ago already, and in many countries, an effort was made to increase the security of masonry buildings without, however, increasing the expenditure too much. We are aware of several methods of iron braces and of beltings which have proved satisfactory. We had likewise probably, together with many other engineers and architects, thought of introducing into masonry structures raising pieces and king-posts of sheet or cast-iron, and between which you could build in stone, brick or concrete. But at first sight it is evident that the expenditure would be increased very much on account of the considerable amount of material, sheet and cast iron, and also of labor, which would be necessitated in these different methods.

At last we got the following idea, the simplicity of which is perhaps its

greatest merit, and which is especially applicable to masonry structures in stone and brick.

Suppose you have a certain number of bricks placed one above the other, just as for a masonry wall, but dry and without any mortar. Then suppose you shake the table on which our supposed wall rests. The bricks will evidently be "disjointed" in every direction. But if this heap of bricks is strongly connected by a string, a wire or a band of iron, is it not true that there will be no more displacement, that there will be no further danger of its falling as a whole either to right or left; that is to say, within or without the structure of which the supposed wall forms a part. The whole novelty of the idea is in that, and we have only now to apply it to building.

On account of the ordinary depth of masonry walls, we can take a part of the wall, having the height of one story, with about the same breadth, to be a heap or agglomeration of bricks or other material, which can be strongly bound together, and in consequence consolidated, as far as the disjointing of the material goes, just as we did above for the heap of bricks.

It will evidently be the same for all the adjoining parts, and finally for all the walls of the building.

Suppose, then, that all these different agglomerations or heaps of masonry are united together, and you will then have a structure quite as homogeneous and capable of resistance by itself as all other masonry structures. Only to it has been added a force of resistance to fracture (or disaggregation of materials) equal to the force of the irons used as links.

We can then formulate our principle in the following manner: Link the masonry in heaps or in connected masses, so that the materials cannot separate nor the walls split.

We have only now to support the walls against a fall either inside or outside the building. The simplest and most reasonable way of doing so seems to be to use strong frames in wood or iron, resting on the ledge formed by the difference in depth of the walls in the different stories and containing the principal parts of the framework of the floor and roof linked together, always bearing in mind that the walls be strongly fastened to the frames, as well as having those different frames solidly connected with one another if there be several partition walls, in each story. If the great extent of the walls require it, you can improve the rigidity of the sides of the squares by iron braces. We have made use of these different methods in almost all our masonry work in Japan.

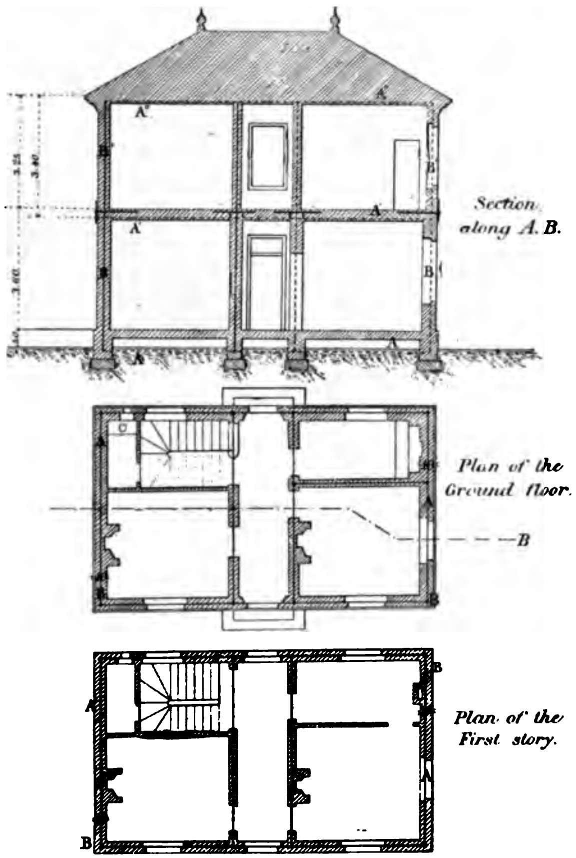
With regard to the novelty of the idea, it should be very cheap, as the use of iron is a great saving of material; that is to say, by subjecting it to the force of traction.

In matter of fact, we are aware that a shank of iron rod, 1 centimetre square in section, supports with very great security a minimum load of 1,000 kilogrammes, and that the snapping of the rod, according to the quality of the iron, can only take place under a load of 4,000 to 6,000 kilogrammes.

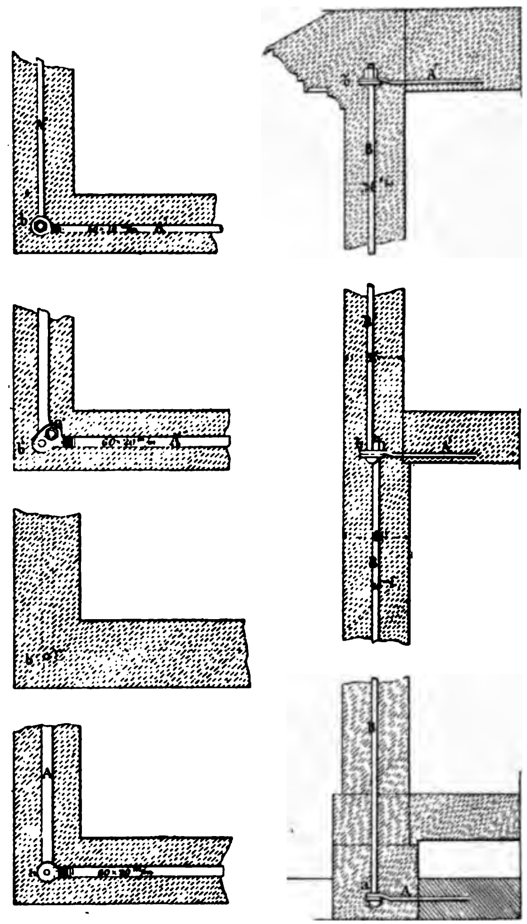
It is apparent from this that with iron of small dimension we can increase in a very great measure the solidity of masonry structures against the minor effects of earthquake.

Application of the Foregoing Principles.

We have now to apply our system.



Scale = 1/50 or 2 centimetres to the metre.



Scale = 1/10 or 10 centimetres to the metre.

DESCRIPTION.

Lay the flat iron bars (A) horizontally in a groove prepared for the purpose a little below the level of the ground and along the middle of the foundation course. Join these bars by means of circular iron rods, passing through holes punched at the ends of the flat bars A when heated.

Give a head to the vertical rods B also while they are heated. When the rods are fixed these heads will go under the horizontal bars A.

The section of the flat bars A is equal to that of the rods B, and the length of the latter corresponds to the height of the story. The maximum length of the bars A nearly equals that of the rods B, so as to enclose almost square masses of masonry.

The upper part of the rods B is either grooved for a screw or bored for a bolt. Once they have been set they will remain perfectly perpendicular.

The masonry work is then completed as usual above the bars A and all round the rods B. You must make use of the best materials where these bars run into each other; that is to say, at the corners of the masses of masonry. You must also adjust the crossings of the masonry round the vertical rods.

When the masonry work is one story high close the divisions of masonry by means of other flat iron bars A′. These flat bars A′ have the same section as the others A, but instead of having one hole at each extremity, they have two, a′ and b: of which a′ contains the upper part of the rod B of the ground floor, and b the lower end of the rod B′ of the first story.

If you do not close the divisions by means of a bolt, you have to fasten the ends of the rods B firmly and with a screw long enough. The first story rods B′ are kept vertical, and then you begin again as for the ground floor.

Our system can be employed for as many stories as required, and when you finally come to the top of the masonry walls, close the divisions by means of flat iron bars A″ which have only one hole b′ at their extremity.

EXPANSION.

Although expansion is hardly appreciable, it is good to take it into account.

We may allow that the extreme 10° to 30° temperature within the wall will never vary beyond—10° to + 30° Centigrade—a range of 40° Centigrade.

The average expansion of iron being 0·0000125 per metre of length for the degree, we shall then have for the limit of expansion of the bars and rods of the ground floor (which are at most 4 metres in length): $0^m,0000125 \times 40° \times 4^m = 0^m{\cdot}002$ millimetres. This gives a maximum expansion of 2 millimetres only. It is good, however, to take it into account, in order to regulate the length of the bars, their assemblage, and fastenings.

The effect of expansion can be done away with by allowing a little play everywhere, and by putting little wedges of fir-wood, for instance, at the ends of the vertical rods, or by other ways.

DIMENSIONS OF THE IRON PIECES.

Section of the Ground Floor Rods—We intend giving the iron pieces, dimensions in proportion to the maximum resistance to fracture, or, what comes to the same, to the resistance against the splitting of the continuous masses of masonry, that is, those which include no doors or windows. If,

then (as in the illustration, p.331), we have on the ground floor, iron rods or bars 4 metres in length, and outer walls $0^m \cdot 40$ centimetres thick, the section of one of such masses of masonry will be:

$4^m \times 0^m \cdot 40 = 1^{mq} \cdot 60$ or 1,600·000 square millimetres.

Let us suppose, then, that there is a split in the mass of masonry, and that this masonry is made of common material and mortar composed of thick lime and mud.

The maximum stress of this brick being (according to Claudel) $0^k \cdot 08$ for the section of a square millimetre, and that of the mortar being $0^k \cdot 04$, we shall take on account of the masonry joints, for maximum resistance to fracture or splitting, the mean of the above values, viz.:

$$0^k \cdot 06 \ldots\ldots (1)$$

We then get for the stress of fracture of the mass of masonry.

$1{,}600{\cdot}000^{mmq} \times 0^k \cdot 06 = 96{\cdot}000$ kilogrammes, which value gives the maximum resistance to the fracture of the continuous mass of masonry of ordinary brick.

Suppose, now that we want to double this maximum resistance; for that, since both rods or bars have a common action, we have only to calculate the section of an iron rod capable of resisting half the above weight, say 48·000 kilogrammes.

The maximum stress of the iron we require is about 40 kilogrammes to the section of a square millimetre.

$$\text{Hence } \frac{48{\cdot}000}{40} = 1{\cdot}200 \text{ square millimetres} \ldots\ldots (2)$$

represents the section of the iron capable of a resistance equal to that we have assumed for the masonry. This corresponds to the circular section of 40 millimetres in diameter (3).

Remark—We have, as a matter of fact, more than doubled the resisting power of our iron walls, for we have supposed continuous masses of masonry, while most of them have a door or window.

Let us then apply our calculations to a mass which has a window $1^m \cdot 80$ high.

The section of the wall in this place will not be more than:

$(4^m - 1^m \cdot 80) \times 0^m \cdot 40 = 0^{mq} \cdot 88$ or 880·000 square millimetres.

But practically we do not consider the masonry to have permanent resisting force of more than 1-10th of its maximum stress.

We then get a coefficient of resistance (1):

$$\frac{0^k \cdot 06}{10} = 0^k \cdot 006 \ldots\ldots (1).$$

Hence $880{\cdot}000^{mmq} \times 0^k \cdot 006 = 5{\cdot}280$ kilogrammes.

This 5·280 kilogrammes finally represent the resisting force of one of our masonry buildings having a window.

So also in building, we must not give our iron pieces a permanent weight of more than 10 kilogrammes per section of a square millimetre, say ¼ of its maximum stress (2).

The best resisting force practically of iron pieces 40 millimetres in diameter (3) will then be:

The sectional area of the iron 40 millimetres in diameter is 1·256 square millimetres:

Thus $1{\cdot}256^{mmq} \times 10$ kilogrammes = 12·560 kilogrammes for each of the bars or rods which have a common action; hence for both 25·120 kilogrammes.

Hence it follows that we have increased resistance to fracture in the proportion of

$$5{,}280 : 25{\cdot}120$$
$$\text{or } 1 : 4{\cdot}75$$

i. e., we have increased almost *five* times the resistance of our walls to the effects of earthquake (at least where there are doors and windows).

Section of the Bars of the First Story—You will find in the same way that to double the resisting power of a mass of masonry, the section of the iron rods of the first story is:

$$\frac{3^{m}{\cdot}40 \times 0^{m}{\cdot}35 \times 0^{k}{\cdot}06}{2 \times 40^{k}} = 892 \text{ square millimetres of sectional area.}$$

$3^{m}{\cdot}40$ = length of the rods or height of the story.
$0^{m}{\cdot}35$ = depth of the walls of first story.
$0^{k}{\cdot}06$ = stress of the masonry.
2 = number of rods or bars having a common action and on the same continuous mass.
40^{k} = stress of the iron pieces.
892 = millimetres of sectional area of a rod or bar of iron corresponding to a circular section of 34 millimetres in diameter.

SECTION OF FLAT IRON BARS.

As we take the masses of masonry to be almost square, the section of the flat iron bars should be equal to that of the circular rods; it is thus easy to determine the dimensions, breadth and depth.

Thus, in the proposed instance, we shall take for the ground floor bars of iron 60 millimetres × 20 millimetres, viz., 1,200 square millimetres in sectional area (this corresponds to the circular bar 40 millimetres in diameter), and for the flat bars of iron of the first story, 50 millimetres × 18 millimetres, viz., 900 square millimetres (this corresponds to the circular iron pieces 34 millimetres in diameter).

Note—The section of the iron pieces of the partition wall could likewise be calculated proportionally to the section of these same walls.

—*Lecasse, in Indian Engineering.*

EDITORIAL OPINION.

FIREPROOF DWELLINGS should be as frequently built as fireproof business houses. By fireproof we do not mean absolutely fireproof, as such a structure is a physical impossibility, so long as inflammable materials in large quantities are used for decorations and furnishings. The burning of such contents will so badly injure a house, the materials of which are incombustible, if not destroy it altogether, that it must be rebuilt. The terrible Andrews calamity in New York City, where the entire residence and nearly all the inmates were burned, was the result of the rapid spread of fire among costly hangings and elegant furniture, and had the building been fireproof its destruction would doubtless have been as complete, but the inmates would have had time to escape.

The city of Denver prohibits by ordinance the erection of frame dwellings inside the corporation, and such an ordinance could be passed by other large cities to great advantage, with an additional clause requiring the use of fireproof construction throughout —at least in the very thickly settled portions of a city. The use of steel beams in place of wood joist is now very common and the extreme cheapness of various concrete steel floors renders a substitute for wood available at a reasonable cost. It is not necessary even to use wood flooring, as a cement wearing surface with a carpet strip around the walls enables a carpet to be laid, or if more expense is allowable tile floors may be used.

We believe that the Vanderbilt mansion at Biltmore, N. C., is entirely of steel and fireproof materials, and it is only a question of a short time until steel shall have entirely superseded wood in dwelling house construction.

THE HEAVIEST LOCOMOTIVE IN THE WORLD was the title under each one of three different pictures which were exhibited recently in as many windows of railway passenger offices in a certain city. No doubt at the time each one was put on exhibition it was the heaviest, but heavy locomotives have been built to so great an extent that what was heavy yesterday is light to-day.

It is only a few years since the 100-ton engine of the Pennsylvania Railroad was the heaviest in use, then a little later the 107.5-ton engine of the Pennsylvania Lines west of Pittsburg was one to be remarked about. Then came the Erie 123.5-ton engine, and a little later the Richmond and Danville R. R. specified one of 135 tons for use in designing bridges, although there was nothing in use on the road of such a weight.

At the present time the engine specified by the Atchison, Tokepa and Santa Fe is one of the heaviest used to design bridges, although recently the Rio Grande has adopted a loading with 150-ton engines—there being, as is usual, two coupled engines followed by 4,000 pounds per lineal foot. The heaviest engines in use on the road weigh 124.3 tons, with the tender loaded, the greatest load on a pair of drivers reaching nearly 40,000 pounds, the actual weight being 39,585 pounds.

Descriptions were published last year of a heavy engine for the Great Northern Ry. weighing 154.4 tons, and much talk was made about it. Upon examination of the wheel spacings and by comparing them with other heavy engines, it was easily seen that it would not be so severe upon a bridge as some of less weight, but with shorter wheel base. When a curve of equivalent uniform load was calculated, and plotted in connection with those of other engine loadings, it was found to be of less effect than many other lighter ones.

If, then, the operating department could always confer with the maintenance of way department before buying new locomotives, it might be possible to construct them with spacings so as to occasion no increase in loads upon the bridges. It would seem that 150 tons ought to be the superior limit for loco-

motive weight, but when the end will be reached no one is prepared to say.

Some locomotives were recently purchased by one of the trunk lines, which were so heavy that when two of them were coupled together for climbing heavy grades the bridges were badly over-stressed. To avoid this, the simple expedient was adopted of placing an idle flat car between them. This answered much the same purpose as greater wheel spacings, although occasioning an increase in the dead weight to be hauled.

THE PLANNING OF HIGH BUILDINGS is a matter of grave responsibility, and it is to be hoped that those having such work in charge appreciate the great care necessary to be exercised. One of these modern office buildings houses during the daylight hours as many often as three or four thousand persons, whose lives and safe keeping depend upon the careful design and construction of the foundations, the steel frame work and the floor systems more especially than upon any of the other features.

It is reputed that the foundations for one enormously tall building (which were made by driving piling, much to the astonishment of many) are very inadequate, some of the piles being only a few feet in length after they were cut off. There is little excuse in not having good foundations, as the pneumatic process is frequently used where rock is within reach, and where it is not, piles *can* be properly driven and in sufficient number, or a concrete and steel foundation can be employed. For the steel frame only the best details should be used, and no experiments tried. The steel should have a minimum thickness of not less than three-eighths of an inch and for parts under great duty, half an inch would be better, inasmuch as the question of rusting has never been satisfactorily exploited. Will some of us now living see the sky-scrapers begin to fall from the rusting out of the steel work? Manifestly not if the metal was properly cleaned of rust before being painted and is kept perfectly dry thereafter. But how are we to know that it is always perfectly dry?

The use of cast iron has been to a great extent condemned by engineers, and also to some extent by architects, and it is to be hoped that it will never be used again for columns in an important building. Mind you, we do not say *cast* columns, for it is to be hoped that *cast steel* will be so cheapened and its use so extended that perfect cast columns of great tensile strength may be obtained.

The fireproof floors are so many that there is some excuse for a mistake being made in selecting a type for use, but we believe that some forms of concrete steel will be the ones to survive, as having the requisite strength and the necessary fire resisting qualities. Besides the dead weight to be carried is so much less, as to cause a great saving in weight of steel work.

There are many other things to be borne in mind, and which come to mind as one rides up and down in the swiftly moving elevators, not the least of which is the safety of the elevator itself. The engineering skill employed in their design should be of the highest class, the inspection of the materials most careful, the workmanship and erection of the very best order and lastly most careful examinations of its safety after erection and from time to time.

These are only a few of the things we think of and mention in the hope that by much repetition they will become engraven on the minds of those engaged on the work.

CURIOSITIES OF SHOP WORK are often seen which are worthy of description as showing the extent to which a poorly equipped contractor will go in an endeavor to do work for which he is not fitted. Practically all modern shops are provided with power upsetters, which will upset rods up to three inches in diameter, and many are provided with hydraulic machines of much greater capacity.

When shops have no upset machines it is customary for them to weld on a piece of larger size bar on which to cut the thread. If the weld has been carefully made it should have a strength of at least 75 per cent of an original bar, so that if the main bar has been stove up and the weld made in the larger size, nearly the full strength of the bar should be developed.

Recently a contractor on an important foundation constructed a coffer-dam by driving sheet piling and instead of bracing across inside, anchor rods through the wales were fastened to "dead men" some distance back. These rods were made by a responsible shop and were "upset" apparently in the proper

way. During the progress of the work, several of the rods stripped off at the upset in a peculiar manner—the entire threaded surface coming off together. Upon investigation is was found that the upsets had been made by slipping a piece of pipe over the original bar and getting a sort of weld between them! The weld was naturally so imperfect that it would carry only a small percentage of the load upon the rod. The result of the failures necessitated expensive repairs to the cofferdam, besides the replacing of the rods and it is only to be wondered at that great loss of life did not ensue, as would have been the case if a large number had stripped at the same time.

We cannot conceive why upsets were not at least welded on in the usual manner—they would have been cheaper than the pipe scheme and immeasurably safer.

THE COMPENSATION OF ENGINEERS is a subject which never loses its interest for members of the profession, because compensation is one of the principal aims of engineers everywhere and of every class. The pay of structural engineers nearly ten years ago was somewhat larger than in almost every other branch. This resulted in a large number of graduates entering upon structural work. The greater supply and the coming on of hard times caused a drop in wages of nearly twenty per cent in most cases and in some a greater reduction.

It had been customary for the graduates to find places at fifty dollars per month at the very start and after a very few years' experience to receive from one hundred to one hundred and twenty-five dollars per month. The custom at the present time is to pay the beginner only thirty-five or forty dollars per month, and the openings at even so low a rate are very scarce. After several years service the pay only reaches eighty to one hundred dollars.

There are, however, signs that the supply and demand are becoming readjusted, and during the present year a scarcity of men will cause wages to advance to their former amounts.

The pay of men in charge of work was not, however, reduced in many cases over ten per cent, and in many instances no reductions were made.

Coming, now, to the pay of the consulting engineers, the scarcity of work and the prevaiing low prices caused many engineers to take work on very small percentages and to charge very small fees. The story has come to us of one engineer who kept busy through the dull times and having at one time more work than he could do, turned some of it over to a brother engineer who was not so fortunate. When the service was performed the second engineer handed in his bill to the first named. With the remark to another, that such low prices were ruining engineering, he multiplied the amount by five, sent the bill to his client and received payment without objection being made. Such a story should not cause the increasing of fees which are already large enough, but it should give courage to those who render satisfactory service to make sufficient charges.

Another engineer was called upon to furnish some information to a firm which would eventually redound to his own benefit, but would do the firm in question no good. The time required to perform the service was so short as to be of no consequence, but a bill was sent in for only a few dollars—so small in fact as to be ridiculous. In such a case it would be wise for an engineer to make no charge, but if he felt impelled to do so, it should be of such an amount as not to make the profession the laughing stock of laymen.

When a slight service is rendered, with other and more important work in prospect, it is customary to charge a nominal fee as a retainer, having it definitely understood as such, and then when the after work is done make such charge in full as is warranted. Nothing is so conducive to a dignified profession as dignified and self appreciative conduct by its members.

Timely Topics.

THE ARCHITECTURAL ELEMENT IN ENGINEERING WORK.

In a recent address by Mr. H. H. Statham, before the Royal Institute, on this subject, after reviewing the older bridges and engineering works where simplicity characterizes them and no effort at adornment was made, he says: "It was within the last quarter of a century or so that the minds of engineers had been poisoned with the terrible ambition to produce 'handsome' structures, and in the endeavor after that they had entered on a field for which their training had in no way fitted them. It seemed impossible to get engineers to understand that the handling of decorative architectural detail was a matter requiring special training."

He might, looking over the same period, characterize the minds of a large class of architects as being "poisoned," for perhaps no greater architectural failures are to be found than in the cases where the idea of adornment has been the leading one. In both cases it has been lack of training and appreciation of what is suitable and fitting that has resulted in unfortunate designs. Most well regulated minds in both professions have come to accept the necessity of a division of the purely structural from the purely artistic features of these callings. It is necessary, however, that there should be a close sympathy between the two, and that they should work in harmony.

A study of the paintings of our greatest artists shows a clear comprehension of anatomy, in other words construction, and so must it be with good architectural designers whether on bridges or buildings. But in this matter of construction the architect has not been slow to recognize the engineer. In the massive buildings, so many of which have grown up lately, the engineer and architect have largely worked together, and the same must be true to effect the best results in engineering works where questions of appearance are concerned. With the growth of our great cities there will come a demand for artistic expression in the great engineering works which develop in the course of their progress. Mere clumsy attempts to furnish bridge communication without regard to appearances will not answer. We are passing beyond the mere utilitarian age into one where the art element has its influence. In these structures the training of the architect in matters of form decoration and the application of ornament are essential. The purely structural features once being decided upon the design should be intrusted to the architect, and this should take place early in the work, in fact should proceed hand in hand with the structure when once it rises above the foundation. Lack of success in architectural treatment of such works often results from the architect being simply called in to apply his architectural features as a finish to an already completed structure. While ornament should be adapted to the construction, the construction should be also adapted to receive it. Then, too, the success from the standpoint of appearance of a bridge or other work of similar magnitude depends far more on the general proportioning of parts than it does on any superficial treatment, and to solve such a problem it should be considered from the start.

We are inclined to sympathize with Mr. Statham's closing sentences when he says: "In the case of bridges which were to be decoratively treated, the engineer should be assisted by an architect, why should it not be put the other way about—that an architect should build the bridge assisted by an engineer? Architects were not familiar with the problems incident to forming foundations in deep water, in the bed of the sea or of a river; but as soon as the structure cleared the water, if it was to be an architecturally treated bridge, it was really more of an architect's business than an engineer's."

This might not altogether meet the views of engineers, but if we are to go on putting up highly decorated structures of this character, it will be found necessary for the architect to put in his work at the beginning—at least of the work above ground. Success in such design, depending as it does so much on surroundings, the whole landscape must be studied and the structure fitted to the place it will occupy, all of which emphasize the necessity of the early arrival of the architect on the ground and the moulding of the design from its beginning, leaving to the engineer to provide foundations and constructive methods.—*Architecture and Building.*

WOOD CREOSOTING.

For many years a problem which has received much careful attention from economists has been that of inventing some process for the treatment of wood whereby its life might be preserved. Wood preservatives of more or less value have followed each other in rapid succession, but there is one process that has proven of marked utility. This is creosoting.

This process of treatment was invented in England and has been in general use there and on the continent for about forty years. During the last ten or fifteen years several plants for wood creosoting have been installed in this country, but from the expense of thus treating woods, and from the lack of general interest in the subject of building permanent woodwork in places where timber is subjected to rapid decay a large number of the plants have been financial failures. However, there are quite a number of successful enterprises of this sort now being operated in the United States.

The specific method by which wood is treated in the creosoting process is thus described in the American Lumberman: Steel tanks six feet in interior diameter and 105 feet in length are usually employed. These tanks are closed at both ends by strong cast iron covers held in place by bolts and eccentrics. Tram rails are laid the length of these tanks, and on them are run steel cars surmounted by cradles practically following the contour of the interior of the tanks. These cradles support the piling or telegraph poles or timbers which it is purposed to creosote. One of the tanks in question will hold about 1,200 cubic feet of ordinary piling or poles. The bottom of the tank is filled with thousands of feet of steam pipe, through which super-heated steam at about 700 degrees is forced. After the ends are closed and sealed, live steam is turned into the tanks, this being superheated by the steam pipes at the bottom of the tanks. After the timber has been subjected to this intense heat for a length of time which experience has determined an exhauster is applied, which extracts practically every particle of sap, albumen and moisture from the wood. This portion of the process being finished, the residue space in the tank is completely filled with dead oil of tar, which has previously been heated. The tank being full, air pressure is applied by means of strong force pumps and the deal oil is forced into the interstices of the wood to the depth and extent desired, a gage accurately registering the quantity with which the timber has been impregnated. The usual amount of deal oil which is forced into the piling or telegraph poles is about twelve pounds to the cubic foot. The residue of oil is then drawn from the tank, the heads taken off and the timber withdrawn for cooling. Immediately upon cooling a chemical action takes place which transforms the dead oil into what is practically an insoluble form. The cost of this treatment is from 20 to 25 cents a cubic foot, which in case of railroad ties, for instance, nearly quadruples their cost.

It is not known how long this treatment will preserve woods, but railroad ties thus treated nearly forty years ago in Great Britain are still in an excellent state of preservation. Within recent years they have been taken up and turned over, but the lower face was apparently as sound as when first put in the ground. For the purposes of timber use in dock building this creosoted material is invaluable, as the teredo will not work in creosoted wood.

There should be and is a growing demand for creosoted woods for piling, telegraph and telephone poles, foundation timbers, telegraph cross-arms and many other purposes, but at the present time there is a menace against its largely increased use from the fact of the limited supply of dead oil of coal tar. This material is a by-product of the distillation of coal tar. The only large quantity of coal tar manufactured comes from gas plants, and there is a gradual diminution and almost ex-

tinction of this industry, owing to gas being supplanted by electric light. Even at the present time more than 50 per cent of the dead oil of coal tar used for creosoting purposes by plants located on the seaboard is imported.

WHAT IS THE EFFICIENCY OF AN AIR COMPRESSOR?

The following question has been brought to my notice:

"Assuming that there is no mechanical friction to an air compressor or blowing engine, and that the machine is complessing air to a pressure of one atmosphere by gage, or two atmospheres absolute, what is the possible efficiency of the machine if it does not compress the air gradually? The writer has in mind a rotary pressure blower, which should not properly be used for an air compressor; but, assuming a blower to be frictionless and to have no leakage, and, disregarding the loss by radiation of heat, what would be the possible efficiency of the blower in compressing to one atmosphere?"

The question is one which might very naturally shape itself in the mind of a good mechanic whò is just beginning to look into the operation of air compression. We have to assume that the air is compressed for some power transmission purpose, and it is therefore a question of the loss of power in the operation of compression, or a question of the power cost of compression. We cannot, as suggested, disregard or ignore the radiation of heat, as the question of efficiency depends entirely upon temperature conditions. Leaving out all consideration of friction and leakage, the entire range of possible efficiency in air compression lies between the compression of the air at initial and constant temperature, or isothermally, and its compression without abstraction of heat during the compression, or adiabatically.

In compressing air isothermally in a cylinder traversed by a piston, the mean effective pressure or resistance for the stroke when compressing to two atmospheres, or, say, 15 pounds gage, and including not only the compression of the air, but its expulsion or delivery into the pipes, is 10.33 pounds. For the same operation, if conducted adiabatically, or without any cooling of the air during the operation of compression, the mean effective pressure is 11.51 pounds. As isothermal compression represents perfect efficiency, the relative cost of adiabatic compression is shown by dividing the one M.E.P. by the other; thus: $11.51 \div 10.33 = 1.114$. The power cost of compressing air to 15 pounds gage cannot, therefore, be made to rise more than 12 per cent above perfect efficiency, so far as the air itself is concerned. The other losses in compression are those of friction and leakage, which can only be ascertained by actual tests, and in the above question we are not invited to look into them. The relative efficiency of a rotary blower as compared with a reciprocating piston machine is all comprised in their differences of friction and leakage, as the air will require the same power for its compression by either means.

The suggestion as to compressing the air gradually is the suggestion of a still rather widely held fallacy. By gradually is rather meant slowly, and the assumption is that if air is compressed slowly enough it will not be heated as much by compression, if, indeed, it is heated at all. The air will be heated precisely the same whether compressed quickly or slowly. If it remains cooler under sufficiently slow compression, it is only because it is actually cooled, or gives off heat to the walls of the cylinder, or whatever it may be in contact with during the compression. There is no saving of power by slow compression over rapid compression except by some cooling of the air that may ensue by the equivalent heating of the cylinder and piston.

The loss by radiation of heat is not a loss but a gain, or saving of power, if it occurs during compression, but is a distinct loss of power after compression and delivery of the air is completed, on account of the consequent reduction of the volume or pressure of the then available compressed air. If the air can be applied to the use for which it is intended before it loses its heat of compression, or when it has lost only a portion of that heat, so much power is saved. For this reason it is not usually satisfactory to consider the efficiency or economy of any given case of air compression without at the same time considering the conditions under which the air is subsequently employed.

If air could be compressed isothermally and then completely re-expanded isothermally, while exerting its full expansive force against

a piston, no loss of power would be sustained at either end of the operation, so far as the action of the air was concerned. This is, however, an impossible condition, either in the compression or in the re-expansion of the air. In the case before us, when compressing air from one to two atmospheres the M.E.P. for adiabatic compression may be taken to be the actual M.E.P., as, when compressing at the speed that would be commercially possible, there would be no appreciable cooling of the air during the operation. Some hydraulic air compressors, in which the air that is being compressed is intimately mixed with the water, do compress the air nearly isothermally, but none of the usual mechanical compressors do this. In compressors working to considerably higher pressures, the familiar device is employed of performing the total compression in stages, or by two or more successive compressions, with a cooling of the air between each two successive compressions, and it is found well worth while to do this, especially, where considerable quantities of air are handled. Much compressed air service is still on so small a scale as to make the arrangement of debatable value in those cases.

In the compression of air the comparative rates of efficiency seem to lie entirely between perfectly isothermal compression on one side, and perfectly adiabatic compression on the other. In the subsequent use of the compressed air adiabatic and isothermal re-expansion should also be the limits of the range of possible efficiency; but there is here an opportunity for a still lower rate of efficiency by the use of the air without any expansion except after release. It is not worth while to show this in connection with a pressure of 15 pounds; but with a pressure of 6 atmospheres, or say, 75 pounds gage, a common working pressure, it is worth while to note the range of theoretical efficiency. We have to note both the volume of air used and the M.E.P. developed in its use. With air at 75 pounds gage, following the piston at full pressure for the entire stroke, we have a volume 1 and a M.E.P. of 75 pounds. With air at the same pressure cut-off at .276 of the stroke and expanding adiabatically to atmospheric pressure at the end of the stroke, the M.E.P. should be 35.23 pounds. With the same air cut-off at .1639 of the stroke and, if it were possible, expanding isothermally to atmospheric pressure at the end of the stroke, the M.E.P. would be 26.65 pounds. Here by dead pressure we have 75 pounds M.E.P. per volume 1; with adiabatic expansion we have $1 \div .276 \times 35.23 = 127.39$ pounds per volume 1, and with isothermal expansion we should have $1 \div .1639 \times 26.65 = 162.56$ pounds per volume 1. Isothermal expansion to atmospheric pressure being 1, the standard of perfect efficiency, we have for adiabatic expansion: $127.39 \div 162.56 = .7836$, and for dead pressure without expansion: $75 \div 162.56 = .4613$.

In the compression of air in the usual way, by a reciprocating piston traversing a cylinder, it is of course desirable to have the clearance as small as possible so that as much of the compressed air may be delivered as possible, but the matter of clearance has little bearing upon the efficiency of the compression, as the re-expanding air gives back the power on the return stroke. But in the subsequent use of the air the matter of clearance is one of great importance, as it always involves loss of power. Where the air is used without expansion the filling of the clearance spaces is an absolute and unmitigated loss, and even where the air is properly expanded in use, only a small percentage is recovered from the air in the clearance.

While considerable attention has been given to securing the best economy in the compression of air, and with quite appreciable results, little indeed has been done toward the economical employment of the air after compression, although in the latter there are much greater possibilities of loss, or of saving, involved than in the former.—*Frank Richards in American Machinist.*

AN IMPROVED METHOD OF MAKING STEEL CASTINGS.

The merits of the Walrand-Legenisel steel process were made the subject of discussion at the last meeting of the American Institute of Mining Engineers. This process practically supplements the Bessemer process in such a way as to permit the making of castings directly from the converter. Its essential feature consists in the addition of ferro-silicon (containing from 10 to 12 per cent of silicon) to the charge in the converter, when the flame drop takes place, and then making an after-blow. The oxidation of the silicon

which takes place generates a large amount of heat, which is imparted to the metal—as the combustion product is not volatile—and the consequence is that the steel becomes strongly superheated. The metal is very fluid, produces castings quite free from blowholes, and permits the making of intricate castings down to a fraction of a pound in weight.

By the usual methods in vogue, the production of sound castings, especially those of small size, has always been attended with great difficulties. The high degree of superheating attained in the new method appears to obviate this difficulty. The new process is successfully employed at large works in France and Germany, and in at least one large works in the United States.—*Journal of the Franklin Institute.*

USELESSNESS OF TESTING OF IRON BRIDGES BY METHOD OF LOADS.

The following article appeared in a recent number of the *Organ für die Fortschritte des Eisenbahnwesens.*

Extract from a communication by F. E. Robertson, dated Calcutta, to the *Bulletin de la Commission internationale du Congres des Chemins des Fer.*

Many engineers regard the testing by loads of iron bridges as an heirloom coming down from the times when a proper comprehension of the matter was non-existant, and which still survives solely from mere custom and from the indifference of the ruling authorities, but which is nevertheless a procedure unworthy of a scientific body.

These testings by loads rest on the assumption that a structure which on the imposition of a load double as great as the permissible one shows no trace anywhere of a possible weakness may be considered to offer the assurance of complete safety.

Of course it may be argued that this practice is neither disadvantageous nor harmful; but to this it may be replied that every useless formality is a deception and therefore bad. The onus lies on the advocates of the method of testing by the imposition of loads of demonstrating as to what points these "testings" can give any information whatever, and in what their indispensableness consists; and further on what grounds the employment of the maximum load is justifiable.

In our opinion the deflection of a structure—assuming that the limit of elasticity of the material is known—can only give information as to the mean stress of the entire cross-section of the individual parts. It leaves us in ignorance as to the condition of the connections, or of a part of the structure which at its point of rupture may possibly be in compression; or as to the location of individual places weakened by rust. Then again it may be fairly asked, why such severe loading? Precisely the same information might be obtained equally well from any other known loading. The conditions laid down which a thorough carrying out of the test by loads require appear to be an outcome of the idea—now unanimously recognized as being erroneous—that the safety of a structure can be directly discovered by experiment.

If these tests rested on scientific principles, and if from the exact determination of the extension of the numbers of the structure it were possible to show the exact distribution of the forces in such members there might be something to be said in their favor: but as actually carried out they give no information whatever as to the safety of the structure; and while they form the most considerable part of the examination of bridges they are, in most cases, probably, entirely misinterpreted.

These tests are defective also from another point of view. For even if we assume that they yield valuable information regarding the stresses occurring in service, of what use would they be, for instance, in structures, such as the Forth bridge, where these stresses form only some 5 per cent of the total stress to which the bridge is subjected? In such a case is the load test anything more than simply a formality conceded to the general ignorance?

Professor Unwin says: "The reason why it has required so much labor to obtain recognition of the importance of Wöhler's experiments is to be attributed to the existence of official regulations as to the limits of stress and to the retention of ideas which have originated only from the habit of following such regulation."

The American engineer, Theodore Cooper, expresses himself similarly. He says: "The determination of the deflection of a bridge,

especially of an old bridge which perhaps has in many thousands of instances been overloaded, simply for the purpose of determining the degree of safety offered by the structure for its further use is such an absurdity that I am astonished to find this idea again coming up at the present day."

According to my way of thinking it is an extravagant absurdity, which should be made an offense cognizable by the police, because it only serves to give the public a warranty of safety which is absolutely worthless.

Remark on the above by the editor of the *Organ:*

As is well-known, the opinions expressed in the above paper have long been strenuously discussed among us in Germany, and have been recognized generally as correct, and as the proper points of view from which to conduct tests, *i. e.,* when tests are made only with the usual working loads of service, and when particular attention is directed to stress-measurements in the individual members, to the coincidence or not of the calculated with the observed deflection, to the detection of possible increase in the permanent deflection.

Extract from Röll's Dictionary. Engineering—Art: "Bridge testing"—by the Translator:

This bridge-testing is not done with the object of convincing experts, *viz.,* the authorities who will have to look after the bridge, that the structure is able to withstand the maximal stresses which it is required to do. That it should not be able to do so cannot for a moment be supposed possible in view of the present state of knowledge of the art of bridge building. Such testing by loads is mainly carried out for the benefit of the public, and mainly to give them a warranty of the durability of bridges which from their appearance—often very bold and airy-looking—might inspire them with distrust: and on this account, if for no other, it is probable that it will long continue to be carried out.

From the scientific side of the matter the testing is supposed to enable a comparison to be made of the elasticity-relations as calculated for the structure with their actually existant values: and also to enable a judgment to be formed of the quality of the work, and particularly of efficiency of the connections, in accordance with rules experimentally determined for the permissible permanent deflection.—*A. Bewley, in Indian Engineering.*

ÆSTHETICS IN BRIDGE DESIGN.

The bars and plates that issue from the steel rolling mill, and which the bridge designer has to work into his structure, are modeled on purely utilitarian principles, and do not lend themselves readily to the attainment of beauty in a roof or bridge. And it may safely be said that the designer takes little or no thought as to how his structure will look to the casual observer; his chief aim being to make the work as light and inexpensive as possible consistently with the strength and rigidity that may be demanded. Hence it is that we have to witness so many hideous iron bridges that are planted in Europe as well as in America. To a professional eye there is undoubtedly a beauty in an iron structure that is finely proportioned, and there is no reason, except deficiency in the artistic sense, why a bridge should be made as ugly as possible. Mr. Oscar Sanne is evidently of this opinion, for in a paper recently read before the Western Society of Engineers he strongly advocates the development of a more ornamental design where circumstances and surroundings warrant such treatment. Let it be granted that we cannot make a bridge of iron or steel to look like a Greek temple, nor produce an endpost that can be compared with a Doric, or an intermediate post with an Ionic column; but we agree with Mr. Sanne's contention that any detail in a bridge can be worked in such a manner that, besides its fulfilment of all requirements as to strength and durability, it may make a pleasing and harmonious impression. In a correctly designed bridge or roof every single part has its absolute meaning, and serves always a certain purpose which even an unprofessional man will look at with a certain amount of satisfaction. Even if he should not be able to understand the reason why this or that detail had to be used, he feels at rest, and the structure gives him the impression of safety. Wherever this condition prevails, one of the first conditions of artistic design is fulfilled. There is generally a fear that any attempt to pay much attention to the æsthetic side in bridge design might increase the cost. It may do so in many cases, but not necessarily; and we think that the draughtsman who delineates a structure with all essentials as to

safety, and at the same time keeps in view the effect its general elevation will have upon the artistic eye at some distance, is the man who shows the highest qualifications for his profession.

IRON BRIDGE BUILDING IN JAPAN.

It is reported that the Japanese government is obtaining plans for the construction of a bridge across the Straits of Shimonoseki, so as to unite the main line of the Kin Sun Railway with that of the Sanyo Railway from Shimonoseki to Hiogo. The straits, at the point referred to, are about one mile in width, and the current through them is very rapid. The bridge, moreover, must be constructed sufficiently high to enable the largest ocean steamers to pass beneath. Thus the undertaking, if successfully carried out, would be one of the greatest engineering feats of its kind. Should the work be undertaken, it is probable that its construction will throw a large amount of business in iron structural work to foreign firms. The work of construction, however, will be undertaken and supervised by Japanese engineers exclusively, but under foreign advice.

PILE DRIVING.

In the paper on "Piles and Pile-Driving," read at a recent meeting of the Institution of Junior Engineers, London, Mr. H. Cartwright Reid, after referring to the antiquity of pile-driving, described various types of piles and methods of driving the same. Bearing piles for remedying an unstable foundation, which was effected by transferring the weight to a firmer material below by consolidating the loose material itself, or by holding the piles in position through the friction of their perimeter; sheet piling for facing to wharves, for cofferdams, and to surround excavations made in water-logged areas, as at Chatham Docks, and in compressible soils to prevent material from escaping from under additional weight. True sawing was essential for water-tightness, and the difficulty of driving regularly was partly overcome by the use of grooved and tongued piles. Correct shoeing and ringing were stated to be of great importance; and details of the shoes in general use, as well as a special shoe for grooved piles, were described. Illustrations of various kinds of cast iron screw piles were shown, and attention was drawn to a recent form of wrought iron and steel built-up pile for driving, rolled from 6½ inches to 13 inches in diameter. Different forms of pile-drivers were also considered, and the modern endless chain driver, as well as the "Lacour" steam monkey, compared with them. The sinking of screw piles, and the advantage of the water jet in sandy soils, were alluded to. The author also dealt with the detrimental effects in practice of high falls of the monkey. These were caused by the rapidity of the blow not allowing the inertia of the pile to be overcome before the full force of impact was developed. Rapidity of blows kept the ground surrounding the pile from close contact, and effected a considerable economy, as the longer the interval between the blows, the less the pile sunk per blow.

ELECTRICAL TRANSMISSION OF POWER IN ENGINEERING SHOPS

One of the American electrical journals has recently published some figures relating to the cost of maintenance of the electrical power-distributing system in the Baldwin Locomotive Works, U. S. A. In this works there are 215 motors in use, varying in size from 2 to 50 horse-power, and having an aggregate capacity of 1,930 horse-power. The total cost of maintenance (labor and *matériel*) is found to be $2,500 per annum, or about 4 per cent on the capital outlay of the plant. This sum of $2,500 is stated to be about the same as that of the older system. The advantages claimed for electrical transmission are: 1. Greater head-room in the shops, and consequent greater facility for using traveling cranes to aid in shifting work. 2. Decrease in transmission losses. One shop that formerly absorbed 150 horse-power is now worked with 80 electric horse-power at the switchboard, a saving of 47 per cent of the power formerly used. A still more striking illustration of loss of power by the older system is that of a planing mill on a Western railroad which when in full work required 500 horsepower. It was found that when no work was passing through the machines, 375 horse-power was still necessary to drive them at the normal speed, and that therefore 75 per cent of the power generated in this mill was used for overcoming frictional resistances of the shafting and machinery. One of the latest important conversions from the older system to

the new in this country is that of Messrs. Willans & Robinson's Engine Works at Rugby. In the Thames Ditton Works, shafting was chiefly used, but in the new Rugby Works shafting is conspicuous by its absence, and electric motors have been installed throughout the shops. This is a change that will undoubtedly extend to other engineering works as the advantages of electrical transmission become better known.—*Trans. Am. I. N. A.*

THE EVOLUTION OF ENGINEERING.*

The field of applied science has of late years become so broad, and the development of its numerous and varied applications so rapid, that in an address of this kind one feels at a loss how and where to begin in the treatment of the subject. We all recognize that with the progress of the age the profession is dividing itself into specialties, and, as the title of our Society indicates, our membership should find abundant opportunities to satisfy their professional ambition by mastering one of its various branches, instead of attempting to acquire proficiency in all. This of itself should be an incentive to future encouragement in the growth and continued prosperity of our Society. The science of engineering does not owe its heritage to any stage in the world's history. While no one race or era can lay claim to its inception or its birth, every civilization may be said to have aided in its development.

If we trace the history of its beginnings, we find, from the records of early human achievements, that the early builders were guided by the knowledge of the results of experiences handed down from generation to generation, rather than by physical laws as established and considered in our enlightened age. From the beginning the progress of engineering development in every nation has been largely influenced by its political history.

Rulers of small states and principalities had little incentive to construct public works. But, as power became centralized and expansion of territory took place, wealth followed, and the perpetuity of civil power in the state was made dependent upon the extension of internal improvements and development of its resources. Wherever the centers of advanced civilization were located, there we find engineering works of importance.

* Read before Louisiana Engineering Society by idney F. Lewis, President; reprint from the Journal.

With the ancient nations, every form of engineering was known which did not require the application of the generated forces. They built canals for transportation and irrigation, reservoirs and aqueducts, docks, harbors and lighthouses. They erected bridges of wood and stone, as well as suspension bridges, laid out roads, cut tunnels, constructed viaducts, planned roofs for their massive buildings, tested the strength of their materials, instituted elaborate systems of drainage, planned fortifications, designed engines of attack, built temples dedicated to their gods and the sun; in fact, covered, to a greater or less degree, all departments of hydraulic, bridge and road, sanitary, military and mechanical engineering, architecture and landscape gardening.

Among the many monuments of ancient engineering we read that the city of Nineveh, which stood on the east bank of the Tigris, was built of enormous dimensions, being fifteen miles in length, nine in breadth and forty-eight in circumference. The houses stood apart, each surrounded by gardens, parks and farms, whose size varied according to the rank and wealth of the respective proprietors. The city was inclosed within one wall as a common defense. This wall was two hundred feet in height, and so wide that three chariots might drive abreast, and upon it were constructed fifteen hundred lofty towers.

The city of Babylon stood in a plain and was perfectly square. The River Euphrates ran through the center of the town, and also supplied water to the ditches, which were excavated in front of the walls. The streets were perfectly straight, and crossed each other at right angles. The city was about fifteen miles in length, and consequently its perimeter was sixty miles. Its houses were built of bricks made of clay, found in its vicinity, sunburnt or burnt in kilns, and cemented with bitumen, with layers of rushes and palm leaves between the strata of brick. The walls of Babylon were three hundred feet high, and eighty-seven feet thick, and pierced by a hundred gates, all made of solid brass. Wide, straight streets, from each of the gates, crossed each other at right angles, which divided the city into six hundred and seventy-six squares, each of two and a quarter miles in perimeter. Some of these squares were used as parks or pleasure grounds. A bridge

passed over the Euphrates between two palaces on the opposite banks, which were also connected by means of a tunnel. The length of the bridge proper was an eighth of a mile, and its width thirty feet, and a long causeway or approach led to the bridge on each side of the river.

The temple of Belus, the supreme deity of the Babylonians, was the most wondrous structure of the city. It was, at its foundation, one-eighth of a mile in length, and about the same in breadth. Its height is said to have exceeded six hundred feet, which is greater than that of the Egyptian Pyramids. It was built in eight stories, gradually diminishing in size as they ascended. Instead of stairs, there was a sloping terrace on the outside, sufficiently wide for carriages to ascend. The temple was adorned with idols of gold. Palaces stood near the temple, and the inclosures and pleasure grounds of one of these palaces covered a space eight miles in circumference. Within its precincts were the celebrated hanging gardens, consisting of terraces one above another, raised upon pillars higher than the walls of the city, well floored with cement and lead, and covered with earth, in which the most beautiful trees and shrubs were planted.

The engineers of ancient Rome were especially noted for their ability to construct durable roads and aqueducts. The great system of military roads was begun by Appius Claudius (B. C. 312), who constructed a paved road to Capua, called from him the Appian way. Others followed after, all issuing from the capital. They bound the different cities and colonies not only together, but to Rome, and were the great highways by which intelligence was speedily carried and the Roman armies marched. In preparing to make a road, two trenches were first dug, parallel to each other, to mark the width. The width was about thirteen feet. The loose earth between these trenches was then removed, and the excavation was continued until a solid foundation was reached. In swampy lands a basis was formed artificially. Above the foundation, small stones were first laid, then a mass of broken stones about nine inches thick, cemented with lime, and above this were fragments of brick and pottery, about nine inches in depth, also cemented. Above this, large polygonal blocks of the hardest stone, fitted and joined with great nicety, were placed. The center of the road was a little elevated, to permit the water to run off. A footpath was constructed on each side. At about the same time (B. C. 313) Appius commenced the system of aqueducts which were to supply the capital with pure water from the Sabine Hills.

No undertakings of the Romans present more striking evidence of their energy, skill and untiring perseverance than the military roads and aqueducts. The latter were constructed at an expense of a vast amount of toil and money. Over hills, valleys and plains, and sometimes in subterranean channels, sometimes on long ranges of lofty arches. These subterranean channels were formed of stone or brick, and were arched in order to keep the water pure. Apertures were made for ventilation. The channel had a gradual slope, and the bottom was coated with cement. When the aqueduct was carried through solid rocks, the rock itself served as a channel. In order that the water should deposit the sedimentary matter which it held in suspension, large receptacles, or ponds, were made at convenient places for it to enter. In the city it was received into a reservoir, and thence conducted, through lead or earthen pipes, into smaller reservoirs, in the different districts which it was to supply. Four of the old Roman aqueducts are still in use. The New River in London, and the Croton aqueducts in New York, are constructed on the plan of the Roman aqueducts. It has been estimated that the total amount of water delivered by these aqueducts is equal to that of a stream twenty feet wide by six feet deep, constantly pouring into Rome at a fall six times as rapid as that of the River Thames, a volume equivalent to over 300,000,000 gallons per day.

They were the most wonderful structures of ancient Rome, and well might excite the admiration expressed by Pliny. "If any one will carefully calculate the quantity of the public supply of water for baths, reservoirs, houses, trenches, gardens and suburban villas, and along the distance which it traverses, the arches built, the mountains perforated, the valleys leveled, he will confess that there never was anything more wonderful in the whole world."

Their public and private baths, amphitheaters, temples and palaces exemplify the type of work constructed during the era of wealth and luxury, when Rome was mistress of the

world. The power of the Roman Empire was upheld as much by the knowledge, genius and energy of its engineers as by its generals.

Rome, in her pristine grandeur, had her Coliseum and her Pantheon. Of the Coliseum Lord Byron, in "Childe Harold," apostrophises:

"While stands the Coliseum, Rome shall stand,
When falls the Coliseum, Rome shall fall,
And when Rome falls—the world."

The monuments of Roman engineering followed the paths of the conqueror; for, in every part of the world, from the shores of the Atlantic to the borders of India, from the Baltic to the Desert of Sahara, the engineer of that period has left the remains of his skill and ingenuity.

During the dark ages, from the downfall of the Roman Empire, about the fifth century, until the beginning of the sixteenth, the sciences were almost lost, being practiced only by the monks and other religious castes. Engineering development, since the beginning, has been influenced by the outgrowth of natural surroundings. In Greece, Italy, Switzerland and France the mountains, streams and gorges turned the attention of the engineer toward tunnels and bridges. So, in the lowlands of Holland and Belgium the continental battles against floods developed a race of engineers with special skill in drainage and dyke building, while in England, surrounded on all sides by a stormy sea, thought was directed to lighthouses, harbors and docks.

In the early part of the sixteenth century, our Dutch ancestors began their work of adding to the area of their country by building canals and dykes and reclaiming land. And, as Holland gradually provided herself with her magnificent system of artificial waterways, her industrial energy was rewarded as the people increased in prosperity, and attained a position of power among the nations of Europe, developing among her people traits of character which were inherited by those who were afterwards to found the metropolis of the New Republic. In Italy the reclamation of its marshes and submerged lands took place in the seventeenth century. In Russia, Peter the Great devoted his time and energy to internal improvements, and laid the plans for a system of inland navigation to connect the new city of St. Petersburg with the Caspian Sea.

Under the reign of Louis XIV of France (1638-1715) systematic improvement of the public highways leading to Paris was inaugurated. The Languedoc Canal was built, and the city of Paris was paved and lighted, during his reign. The Academy of Inscriptions in 1663, the Academy of Sciences in 1666, and that of Architecture in 1671, were founded, and the "Commissary General of Fortifications" was created by him. "L'ésole des ponts et Chaussées" was established in 1720, and in its walls have graduated many able and practical engineers. In 1803, Napoleon Bonaparte, during his Consulship, founded the University of France, and, three years later, in 1806, he removed the Military School from Fontainebleau to St. Cyr, and it has furnished France and the world with many distinguished military and civil engineers. Although England produced eminent engineers in the sixteenth and seventeenth centuries, she was dependent, for her engineering, even more than for her pictures and music, upon foreigners. Technical knowledge lay dormant with her people until the steam engine was introduced. At the time when Holland had made great progress in internal improvement, and in her systems of water communication, and when France, Germany, and even Russia had opened up important lines of inland navigation, there was not a single canal in all England, and her common roads were about the worst in Europe. The Flemings introduced cloth making and linen weaving, and the first windmills and water-mills, while the Dutch introduced the manufactory of pottery, and the first engine for pumping purposes. The first cannon cast in Sussex county was cast by a Frenchman, and the great level of the Fens was drained by Vermuyden, a native of Zealand. A German established the first paper mill at Dartforth, and the first mines were worked by Germans under the reign of Queen Elizabeth.

In the latter part of the eighteenth century attention was directed to the betterment of her highways and internal improvements, and, from this period on, her native engineers have constructed a magnificent system of canals, turnpike roads, bridges and railways. They have built lighthouses (finger posts of the sea) around the coast.

They have hewn out and built docks and harbors for the accommodation of a gigantic commerce, whilst their inventive genius has